NOAA Technical Memorandum NMFS-SEFSC-672
doi:10.7289/V5SF2T46

ESTIMATION OF MARINE MAMMAL BYCATCH MORTALITY IN THE GULF OF MEXICO SHRIMP OTTER TRAWL FISHERY

BY

MELISSA S. SOLDEVILLA, LANCE P. GARRISON,
ELIZABETH SCOTT-DENTON, AND JAMES M. NANCE

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
75 Virginia Beach Drive
Miami, Florida 33149

February 2015

NOAA Technical Memorandum NMFS-SEFSC-672
doi:10.7289/V5SF2T46

ESTIMATION OF MARINE MAMMAL BYCATCH MORTALITY IN THE GULF OF MEXICO SHRIMP OTTER TRAWL FISHERY

BY

MELISSA S. SOLDEVILLA
LANCE P. GARRISON
ELIZABETH SCOTT-DENTON
AND JAMES M. NANCE

Southeast Fisheries Science Center
National Marine Fisheries Service
75 Virginia Beach Drive, Miami, Florida 33149

U.S. DEPARTMENT OF COMMERCE
Penny Pritzker, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Kathryn D. Sullivan, Under Secretary for Oceans and Atmosphere

NATIONAL MARINE FISHERIES SERVICE
Eileen Sobeck, Assistant Administrator for Fisheries

February 2015

NOTICE

This report should be cited as follows:

Soldevilla, Melissa S.[a], Garrison, Lance P.[a], Scott-Denton, Elizabeth[b], Nance, James M.[b] 2015. Estimation of Marine Mammal Bycatch Mortality in the Gulf of Mexico Shrimp Otter Trawl Fishery. NOAA Technical Memorandum NMFS-SEFSC-672, 70 p. doi:10.7289/V5SF2T46

Author Addresses:

a. Southeast Fisheries Science Center, NOAA National Marine Fisheries Service, 75 Virginia Beach Drive, Miami, FL 33149
b. Southeast Fisheries Science Center, Galveston Laboratory, NOAA National Marine Fisheries Service, 4700 Avenue U, Galveston, TX, 77551.

Copies of this report can be obtained from:

Director, Protected Resources and Biodiversity Division	or	National Technical Information Center
Southeast Fisheries Science Center		5825 Port Royal Road
75 Virginia Beach Drive		Springfield, VA 22161
Miami, Florida 33149		(800) 553-6847 or (703) 605- 6000
		http://www.ntis.gov/numbers.htm

PDF version available at www.sefsc.noaa.gov

Cover photograph: Common bottlenose dolphin in South Carolina, June 2005. Photo was edited to remove vessel name for privacy protection.
Photo Credit: NOAA/NOS under General Authorization LoC 1064-1748

EXECUTIVE SUMMARY

Bycatch in fishery gear is a leading source of mortality for marine mammals; however annual mortality of marine mammals in the Gulf of Mexico shrimp otter trawl fishery has not been previously estimated. Simple extrapolation of dolphin bycatch rates with respect to the percentage of the fishery covered by NMFS's Observer Program suggests annual bycatch mortality could be substantial. This study estimates annual bycatch mortality of Gulf of Mexico common bottlenose dolphin (*Tursiops truncatus*) and Atlantic spotted dolphin (*Stenella frontalis*) in the shrimp otter trawl fishery to document the fishery's impact for future management and conservation of these stocks. Stocks which may be affected by the fishery include one spotted dolphin stock, one bottlenose dolphin continental shelf stock, three bottlenose dolphin coastal stocks, and 31 bay, sound, and estuary (BSE) bottlenose dolphin stocks.

Mortality estimates are calculated from shrimp fishery effort data and NMFS's Observer Program bycatch data. Fishery effort data are stratified by state area [Texas, (TX), Louisiana (LA), Alabama/Mississippi (AL/MS), and Florida (FL)], season (winter, summer, and fall), and depth zone (inshore, nearshore, and offshore). Bycatch rates are calculated from Observer Program data aggregated over the 1997-2011 period under two stratification scenarios (2-area strata, and 4-area strata), and under two assumptions about the species identification of unidentified dolphins in bycatch (all unidentified dolphins are identified as either bottlenose dolphins or spotted dolphins to provide minimum and maximum bounds on species stock mortality estimates). Annual mortality estimates are calculated for the years 1997-2011 from stratified annual fishery effort and aggregate bycatch rates, and a 5-year unweighted mean mortality estimate for 2007-2011 is calculated for Gulf of Mexico dolphin stocks. The BSE stock mortality estimates are aggregated at the state level as this is the finest spatial resolution available for fishery effort.

Resulting bycatch mortality estimates indicate that under both stratification scenarios and both species identification scenarios, bycatch mortality estimates exceed 10% of potential biological removal (PBR) for Western Coastal and Northern Coastal bottlenose dolphin stocks. It is possible that the PBR threshold has been exceeded for LA BSE and AL/MS BSE bottlenose dolphin stocks, although further data on both abundance and bycatch rates in inshore waters are required to determine whether this has occurred. Other stocks which may be at risk from shrimp otter trawl fishery bycatch include the TX BSE and FL BSE bottlenose dolphin stocks and the Atlantic spotted dolphin stock, while the Eastern Coastal and Continental Shelf bottlenose dolphin stocks are at lower risk and approaching the zero mortality rate goal (i.e., under 10% PBR).

These results are subject to a number of limitations, and potential bias and variance of stock bycatch mortality estimates are described. The greatest sources of error and bias come from inadequate knowledge of both the fishery and the stocks it impacts including: 1) distribution of fishery effort in inshore waters, 2) bycatch rates of dolphins in inshore waters, 3) stock abundance in inshore waters, and 4) whether skimmer trawls and non-commercial fisherman catch dolphins. Suggested research to improve bycatch mortality estimation include: 1) increasing observer coverage overall, 2) extending observer coverage into inshore waters, including skimmer vessels and state-permitted vessels, 3) use of electronic logbooks or other methods to understand inshore fishery effort distribution as it relates to BSE dolphin stocks, 4) abundance surveys of BSE dolphin stocks, and 5) photographic and genetic sampling of bycaught dolphins.

Operational, gear, and tow characteristics were examined to better understand risk factors that may inform the development of potential mitigation measures. Dolphin bycatch most commonly occurred as entanglements in TED nets and lazy lines, and modifications of these gear components may offer promise for reducing bycatch mortalities. Potential risk factors that may be worthy of further investigation include extended tow durations, TED nets with smaller widths, time of day, and season.

While several analyses were conducted and presented to represent the range of possible annual bycatch mortality estimates due to data gaps and uncertainties, we recommend use of 1) the 4-area stratification as this best represents differences in the fishery across states, while recognizing zeros in some strata are due to low effort, and 2) the worst-case scenario species identification for each species to ensure the precautionary approach is used.

The results presented in this technical memorandum provide the first annual mortality estimates for Gulf of Mexico dolphin stocks from the shrimp trawl fishery, as required under the Marine Mammal Protection Act to document the status of these stocks.

TABLE OF CONTENTS

INTRODUCTION

Marine Mammals and the Bycatch Problem

Bycatch, the unintentional catch of non-target species during fisheries operations, is a leading management concern for US fisheries (Moore et al. 2009, Reeves et al. 2013), including the Gulf of Mexico shrimp trawl fishery (Scott-Denton et al. 2012). The shrimp trawl fishery has been the focus of federal management actions for over two decades due to significant bycatch of finfish species, including red snapper, groundfish, Atlantic croaker and longspine porgy, and protected species, including sea turtles (Pellegrin Jr. 1982, Henwood & Stunz 1987, Nichols et al. 1987, Alverson et al. 1994, NMFS 1995, NMFS 1998, Epperly et al. 2002, NOAA 2012, Scott-Denton et al. 2012, Waring et al. 2012). Since 1991, the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) and the Gulf and South Atlantic Fisheries Foundation (Foundation) have worked together to evaluate and subsequently require gear modifications including bycatch reduction devices (BRDs) and turtle excluder devices (TEDs) to reduce the bycatch of high-profile species including red snapper and sea turtles, respectively (Epperly et al. 2002, Epperly & Teas 2002, Scott-Denton 2007, Scott-Denton et al. 2012). Additionally, under the authorization of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) and the Endangered Species Act (ESA), NMFS and the Foundation implemented voluntary observer programs in 1992 to characterize shrimp trawl bycatch and evaluate gear types for bycatch reduction (Scott-Denton et al 2012). Historically, voluntary program participation has been sparse and non-systematic, making statistical bycatch evaluation difficult. In July 2007, the NMFS Observer Program became mandatory for all federally-permitted Gulf of Mexico commercial shrimp vessels in order to improve both the statistical evaluation of bycatch and bycatch reduction measures (Federal Register 71:56039–56047, 26 September 2006), and observer coverage of the approximately 1,438 federally-permitted Gulf of Mexico vessels approached 1% of hours actively fished in 2011 (NOAA 2012). In addition to monitoring finfish and sea turtle bycatch, the Observer Program also monitors marine mammal bycatch. While incidental bycatch in fisheries is the primary threat to many US marine mammal populations (Read et al. 2006) and marine mammal bycatch has been documented in the Gulf of Mexico shrimp trawl fishery (Scott-Denton et al.

2012), total annual mortality from marine mammal bycatch has not been estimated previously for the fishery (Waring et al. 2012).

The US manages marine mammal populations and anthropogenic activities that affect them under the Marine Mammal Protection Act of 1972 as amended in 1994 (MMPA) and the ESA. While the MMPA prohibits the take of all marine mammals in US waters, and by US citizens on the high seas, the Act provides an exemption for takes incidental to commercial fishing and has laid out specific provisions for reducing incidental take[1] (MMPA §118). The MMPA mandates that NMFS estimate stock[2] abundance and commercial fishery interactions that lead to mortality or serious injury[3] (MSI) to assess the status of each stock and to identify those stocks that may be strategic (see below) and require additional management. By incorporating stock abundance estimates, potential population growth rates, and an uncertainty factor related to stock status, NMFS estimates the potential biological removal (PBR) for each marine mammal stock. The PBR measure provides a conservative threshold of total anthropogenic mortality that can be sustained by a stock, and when exceeded, indicates a stock should be classified as strategic (Barlow et al. 1995, Wade & Angliss 1997, NMFS 2005). A strategic stock is one which A) has direct human-caused mortality which exceeds the stock's PBR level, B) is declining and likely to be listed as threatened under the ESA, or C) is listed as threatened or endangered under the ESA or as depleted under the MMPA.

Based on the frequency of observed MSI of marine mammals from interactions with commercial fisheries with respect to each mammal stock's PBR, all commercial fisheries are classified into one of three categories (I, II, III with I being of the greatest concern) and are included in the annual List of Fisheries (LoF) that is maintained by NMFS. Commercial fisheries are classified as Category II fisheries if they contribute MSI removals between 1 - 50%

---

[1] As defined by the MMPA, take means to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal. Throughout this report, the term take refers to any observed bycatch interaction, including those that may not result in mortality.

[2] As defined by the MMPA, the term "stock" means a group of marine mammals of the same species or smaller taxa in a common spatial arrangement, that interbreed when mature.

[3] Any injury that will likely result in mortality (50 CFR 216.3). Throughout this report, the term bycatch mortality is used to indicate MSI bycatch interactions.

of PBR to a marine mammal stock subject to mortalities totaling at least 10% of PBR from collective fisheries mortality sources. Those which remove at least 50% of PBR are classified as Category I fisheries. When the total MSI from a given fishery exceeds 10% of PBR for a strategic stock (Category I and II fisheries), incidental takes cannot be considered insignificant (zero mortality rate goal) and a Take Reduction Plan may be developed to reduce bycatch from a given fishery to insignificant levels (NMFS 2005). In the 2011 LoF (75FR 68468, November 8, 2010), the Southeastern US Atlantic, Gulf of Mexico Shrimp Trawl Fishery was elevated from a Category III to a Category II fishery based on 11 marine mammal MSI interactions [7 unidentified dolphins, 4 common bottlenose dolphins (*Tursiops truncatus*)] observed in the Gulf of Mexico by the shrimp trawl Observer Program during 1993-2010, and additional documentation of 13 dolphin mortalities [1 Atlantic spotted dolphin (*Stenella frontalis*), 12 common bottlenose dolphins] in Southeast US research trawl operations, and/or sea turtle relocation trawls prior to 2010 (10 of those mortalities occurred during 2002 – 2010) (Wade & Angliss 1997, Waring et al. 2012). Although the shrimp trawl fishery includes both southeastern US Atlantic and Gulf of Mexico waters, more than 95% of Observer Program effort and all Observer Program marine mammal takes have occurred in the Gulf of Mexico. The remainder of this study focuses on the Gulf of Mexico portion of the shrimp trawl fishery only.

The Gulf of Mexico Shrimp Trawl Fishery

The commercial Gulf of Mexico shrimp trawl fishery is one of the largest and most economically important fisheries in the southeastern US. The fleet includes more than 4000 vessels of which approximately 1500 are federally permitted[4]. Shrimp catch from the Gulf of Mexico made up 2.58% by weight of the total US commercial fishery catch between 1997-2011, representing 10.86% of the total dollars brought in from commercial fishing (NOAA 2013a). From 1997-2011, landings of all shrimp species in the Gulf of Mexico averaged 238.8 million lbs (heads-on) valued at an average of $419.6 million per year (NOAA 2013a). The shrimp trawl fishery operates year-round in the Gulf of Mexico, with highest effort occurring May through

[4] Federal permits are required for all commercial shrimp vessels that fish in Federal waters of the Gulf of Mexico. Federal waters range from 9 to 200 nautical miles off the coast of Florida and Texas and from 3 to 200 nautical miles off Alabama, Mississippi, and Louisiana.

December (Nance 1993). The target species of the commercial Gulf of Mexico shrimp trawl fishery are primarily three species of panaeids [brown shrimp (*Farfantepenaeus aztecus*), pink shrimp (*F. duorarum*), and white shrimp (*Litopenaeus setiferus*)], and to a lesser extent, rock shrimp (*Sicyonia* spp.), Trachypenaeus shrimp (*Trachypenaeus* spp.), seabobs (*Xiphopenaeus kroyeri*), and royal red shrimp (*Pleoticus robustus*) (NOAA 2002, Scott-Denton et al. 2012). In the western Gulf of Mexico (from northwestern Florida through Texas), white shrimp and brown shrimp are the main targets of the shrimp trawl fishery. Main fishery activity extends throughout estuarine waters and coastal waters of less than 10m depth for both species, and extends out over shelf waters to 120m depth for brown shrimp (Nance et al. 2010, Caillouet Jr et al. 2011). White shrimp have high fecundity and may spawn multiple times per year; under favorable environmental conditions a small number of spawners can produce a large year-class (Neal & Maris 1985, Nance et al. 2010). Peak landings of white shrimp occur from August to December (NOAA 2013b). Brown shrimp also produce annual crops (Neal & Maris 1985) with recruitment to the fishery occurring in May–July (Rothschild & Brunenmeister 1984). Though their life spans are approximately 2 years, most are harvested within 6 months of age (Baxter 1971), leading to state and federal fishery closures off Texas from mid-May to mid-July to enhance production. Peak landings of brown shrimp occur during May-October (NOAA 2013b). In the eastern Gulf of Mexico, pink shrimp are the main fishery target, followed by rock shrimp. The primary pink shrimp fishing grounds consist of a small group of islands and reefs off southwestern Florida (Hart et al. 2012) and peak landings occur during November to June (NOAA 2013b). Rock shrimp are found in 11-80m depth waters and may spawn multiple times between November and January (Kennedy et al. 1977). In the Gulf, rock shrimp landings occur at relatively low levels which fluctuate monthly and annually with no discernible trend (NOAA 2013b).

An understanding of the shrimp trawl fishery gear usage and operations is necessary to understand and mitigate interactions that may lead to bycatch. The US shrimp trawl fishery and its operations have been well characterized previously (Jenkins 2012, Scott-Denton et al. 2012). Briefly, the two main gear types used by the shrimp trawl fishery are otter trawls and skimmer trawls. Otter trawls have been used throughout Gulf of Mexico fishing grounds since 1913 (Jenkins 2012). During fishing operations with otter trawls, two outriggers, each equipped with one or two relatively fine-meshed nets of 30-50 ft headrope length, are lowered over the water, for a total of two or four nets (Appendix A). Wooden doors at the net edges spread the nets open as they are towed. A tickler chain, looped between the doors, is dragged along the bottom ahead of the net to startle shrimp off the seabed and into the nets. Various configurations of net design, lead ropes, and headrope floats can be used to influence the shape of the net in the water. The net tapers from the mouth at the front to the throat at the back to form a funnel with which shrimp are collected into a netbag, or codend, attached behind the throat. A lazy line, attached to the codend, aids in bringing the net on board for emptying (Maril 1983, 1995, Maiolo 2004). A variety of TED and BRD designs are approved for use in the Gulf of Mexico shrimp trawls, and are required to be used in otter trawls for sea turtle and finfish bycatch mitigation, respectively. These devices are integrated into the main body of the net, ahead of the codend, enabling the escape of larger animals while retaining shrimp catch (Jenkins 2012, Scott-Denton et al. 2012).

The shrimp trawl fishery is limited to the use of otter trawls in oceanic waters, while both otter trawls and skimmer trawls are used in the shallow inshore waters of the bays, sounds and estuaries. The use of skimmer trawls in the inshore waters of Louisiana, Alabama, and Mississippi has been increasing over the last two decades (Hein & Meier 1995, Epperly et al. 2002, Scott-Denton et al. 2006, Price & Gearhart 2011) due to improved catch of white shrimp, ease of use in shallow waters, and reduced finfish bycatch compared to otter trawls (Coale et al. 1994). Skimmer trawls are pushed through the water near the surface making them more effective at catching white shrimp which frequently jump over otter trawl nets. The use of skimmer trawls accounts for over 48% of inshore effort in Louisiana, Alabama, and Mississippi waters, however, they have had limited Observer Program coverage (approximately 1200 hours since 2005), with the majority of Observer Program effort in Louisiana waters (Scott-Denton et al. 2006, Pulver et al. 2012). In Texas and Florida, skimmer trawls are not allowed and only otter trawls are used in the inshore waters of these states. Skimmer trawls are not included in this study due to limited Observer Program effort.

A third trawl type, the roller trawl, is mainly used in Florida inshore waters for bait shrimp (Epperly et al. 2002, NMFS 2013b). Roller trawls, characterized by a mouth formed by a rigid frame and grid of vertical bars spaced less than 3” apart, rollers on the lower horizontal part of the frame, no boards, doors or similar devices, an opening size less than 16’ wide, and short tow durations (<25 min) (Berkeley et al. 1985), are unlikely to entrap marine mammals within the nets and are not included in this study.

Gulf of Mexico Inshore, Coastal, and Shelf Delphinid Stocks

Observed marine mammal bycatch in the Gulf of Mexico shrimp trawl fishery includes six common bottlenose dolphin interactions during 1993-2012. Common bottlenose dolphins (hereafter referred to as bottlenose dolphins) are currently managed by NOAA-NMFS as 36 distinct stocks within the Gulf of Mexico. These include one oceanic, one continental shelf, three coastal (Western Coastal, Northern Coastal, and Eastern Coastal), and 31 bay, sound and estuary stocks (Waring et al. 2014, 2015 in review). The Northern Gulf of Mexico Oceanic Stock is found in waters deeper than 200 m, outside of shrimp trawl fishing areas, and is unlikely to interact with the fishery. The management boundaries of the Gulf of Mexico Continental Shelf Stock are the 20-m and 200-m isobaths, and the three coastal stocks are bound by shore, barrier islands, or bays and the 20-m isobath. Additional climatic and oceanographic boundaries delineate the three coastal stocks such that the Gulf of Mexico Eastern Coastal Stock ranges from 84^{o}W to Key West, FL, the Gulf of Mexico Northern Coastal Stock ranges from 84^{o}W to the Mississippi River Delta, and the Gulf of Mexico Western Coastal stock ranges from the Mississippi River Delta to the Texas/Mexico border (Figure 1). Ranges of the Western Coastal, Continental Shelf, and Oceanic stocks may continue into Mexican waters and the Oceanic stock range also may continue into Cuban waters. Gulf of Mexico Bay, Sound, and Estuary (BSE) stocks were delineated in each of 31 areas of nearly contiguous, enclosed, or semi-enclosed bodies of water adjacent to the US Gulf of Mexico based primarily on studies in two regions, Sarasota Bay, FL and Galveston Bay, TX in the 1970s and 1980s, which indicated bottlenose dolphins are resident in these bays. Subsequent studies using photo-identification and/or telemetry methods have all supported high degrees of residency in the individual bays, sounds and estuaries that have been studied (Waring et al. 2012), and limited movements into the Gulf. Genetic evidence supports discrete BSE stocks (Duffield & Wells 2002) and differentiation among BSE stocks and coastal stocks (Sellas et al. 2005). Population structure, as evidenced by genetics (e.g. Rosel et al. 2009), is an area of active research and its implications for stock management remain to be determined (Vollmer 2011, Vollmer & Rosel 2012). Two bottlenose dolphin ecotypes, coastal and offshore (Hersh & Duffield 1990, Mead & Potter 1995), are found in the Gulf of Mexico (Vollmer 2011) but their exact distribution is unknown. The Oceanic stock is thought to be composed entirely of the offshore ecotype, while Continental Shelf stock composition is less certain. The coastal stocks and BSE stocks are thought to be solely of the coastal ecotype. Knowledge of seasonal movements of stocks is limited (e.g. Irvine et al. 1981, Fazioli et al. 2006). Spatial overlap may occur between BSE and coastal stocks where their distributions meet, and likewise the Continental Shelf stock may overlap with coastal and Oceanic stocks where their distributions meet; for these stocks, crossing of "stock boundaries" is likely to occur. Abundance estimates for most of these stocks are uncertain, as survey data are older than eight years (Table 1). Though insufficient data are available to determine stock status with respect to Optimum Sustainable Population (OSP) size or population trends, the Northern Coastal and Western Coastal stocks were recently elevated to strategic stock status due to an ongoing unusual mortality event (UME) of unprecedented size (NMFS 2013a). Since February 2010 more than 1000 bottlenose dolphins have stranded between the Texas/Louisiana border and Franklin County, Florida and the numbers continue to increase (as of November 2014). The potential cause(s) of this UME is still being investigated as is its potential relationship with the extensive Deep Water Horizon oil spill of April – July 2010. All BSE stocks are considered strategic due to their small population sizes and corresponding low PBR, and many are also impacted by the ongoing UME (Waring et al. 2012).

More than half of marine mammal bycatch incidents (eight) observed in the Gulf of Mexico shrimp trawl fishery during 1993-2012 are of dolphins unidentified to species. Only two delphinid species, bottlenose dolphins and Atlantic spotted dolphins (*Stenella frontalis*), are commonly found in waters where the shrimp trawl fishery operates (Scott 1990, Mullin & Hansen 1999), so these takes may be from either species. Although no confirmed Atlantic spotted dolphin takes have been observed by the Observer Program, this species has been documented foraging around shrimp trawls in the Gulf of Mexico (Caldwell 1955, Delgado Estrella 1997, Fertl & Leatherwood 1997), and was documented as bycatch in the Gulf of Mexico on several occasions in the 1980's (Ford 1991 pers. comm. in Fertl & Leatherwood 1997). Additionally, two Atlantic spotted dolphin bycatch mortalities were documented in research shrimp trawls, one in the Atlantic and one in the Gulf of Mexico.

The Northern Gulf of Mexico stock of Atlantic spotted dolphins (hereafter referred to as spotted dolphins) is genetically distinct from the western North Atlantic stock (Adams & Rosel 2006, Viricel 2012), consists of the larger, heavily spotted continental shelf morphotype (Perrin et al. 1987, Fulling et al. 2003, Mullin & Fulling 2004, Viricel 2012), and has an estimated abundance of 37,611 animals (Table 1, Fulling et al. 2003, Mullin & Fulling 2004, Mullin 2007). Gulf of Mexico spotted dolphins occur most commonly in shelf waters deeper than 10-20m (Davis et al. 1996, Mullin & Hansen 1999, Fulling et al. 2003, Griffin & Griffin 2003, Mullin & Fulling 2004, Maze-Foley & Mullin 2007) and in greater densities in the eastern than the western Gulf of Mexico (Mills & Rademacher 1996, Fulling et al. 2003). Their range almost completely overlaps with that of the Continental Shelf stock of bottlenose dolphins. Knowledge of spotted dolphin seasonal movement patterns is limited (Caldwell & Caldwell 1966, Fritts et al. 1983, Mills & Rademacher 1996, Griffin & Griffin 2004). Spotting in spotted dolphins increases with age and young animals can be difficult to distinguish from bottlenose dolphins (e.g. Herzing 1997).

Bycatch Estimation Overview

Methods to estimate bycatch from observer program data vary across species and fisheries due to differences in available data, bycatch rates, and study designs. Methods include: a) multiplying catch rates determined from observer data by estimates of total fishing effort (NEFSC 1992, Lawson 1997, Romanov 1997, Forney et al. 2001, Carretta et al. 2005, Larese & Coan Jr 2008, Larese 2009, Scott-Denton et al. 2011, Carretta & Enriquez 2012, Scott-Denton et al. 2012); b) multiplying catch ratios determined from observer data by the total catch of target species (Bisack & DiNardo 1992, Vølstad et al. 1997, Hay et al. 1999, Lennert-Cody 2000, Perez 2006, Orphanides 2009, Orphanides 2013); c) predicting catch per effort with regression models parameterized with observer data and applied to total effort (Garrison 2003, Garrison et al. 2009, Orphanides 2009, Rossman 2010, Warden 2010, Warden 2011, Murray 2013); d) predicting the catch per set with a model parameterized with observer data and applied to logbook data (Kleiber 1998, McCracken 2000); or e) summing observed takes with the product of catch rates from observer data by unobserved fishing effort from logbook data (Northridge 1996). Depending on the amount and type of data available and bycatch rates, a time-area stratification design is typically applied or data may be pooled over time and geographic area to estimate simple ratios.

Yeung (1999) determined that marine mammal bycatch estimates for the US Atlantic long-line fleet were insensitive to stratification, whereas pooling increased precision. Annual mean catch rates per sampling unit (e.g. trip) or annual catch rates determined by pooling observed bycatch per year and observed effort per year may be used to estimate total annual bycatch. Mean catch rates account for variability in effort among sample units and provide a measure of standard error (Levy & Lemeshow 2011). When possible, bycatch is correlated with, or modeled on, associated data including target species, gear type, area of capture or other relevant variables. Often this is not possible, such as when there is low observer program coverage or low catch rates, as is typically found for high-trophic level species like marine mammals. The degree of uncertainty in bycatch estimates has been evaluated with standard errors or confidence intervals based on a large-sample approximation (Lawson 1997, Romanov 1997) or a bootstrap procedure (Kleiber 1998, McCracken 2000, Carretta et al. 2005, Larese & Coan Jr 2008, Larese 2009).

Study Goal

The goal of this study is to estimate the magnitude of the bycatch of the bottlenose dolphin and spotted dolphin stocks by the Gulf of Mexico shrimp trawl fishery, for use in future management and conservation decisions. There is considerable uncertainty about the magnitude of bycatch mortalities in the Gulf of Mexico shrimp trawl fishery. In this report, estimates of annual marine mammal stock bycatch mortality are calculated for otter trawl gear in the commercial Gulf of Mexico shrimp trawl fishery for the years 1997-2011. Additionally, unweighted five-year mean estimates from 2007-2011 are provided. Annually-aggregated bycatch rates (catch per hour fished) for otter trawl gear are quantified based upon observer data from 1997-2011, stratified by fishing area, depth, and season. The estimated bycatch rate is then multiplied by the total annual fishing effort (hours fished) estimated from landings and port interviews for each stratum. Stratified bycatch mortality estimates are summed within dolphin stock distributional ranges to obtain estimates of total annual interactions with otter trawl gear for the bottlenose dolphin and spotted dolphin stocks expected to be interacting with the fishery. Best-case and worst-case bycatch mortality estimates are developed for the stocks to account for uncertainty in species identification of some documented marine mammal takes. Sources of variability and bias in bycatch mortality estimates are discussed. These represent the first annual bycatch mortality estimates for this fishery and provide important information for evaluating the status of Gulf of Mexico bottlenose dolphin and spotted dolphin stocks.

METHODS

Data Sources

Fishery Effort Data

Total effort data for the commercial Gulf of Mexico shrimp trawl fishery, required to estimate annual bycatch mortalities of marine mammals, are obtained from modeled effort parameters derived by Nance et al. (2008) and summarized here for clarity. Stratified effort estimates (for both otter and skimmer trawls) are modeled from landings data collected by seafood dealers and port agent interviews with fishermen (Nance 1992, Nance 2004, Nance et al. 2008). Seafood dealer reports provide monthly data on total pounds of catch per species in 21 statistical subareas and 9 depth zones (Figure 1) (Patella 1975). Shrimp catch per unit effort (CPUE) in each stratum is obtained from port agent interviews with fishermen at the termination of their trips and by electronic logbooks (ELB) since 2006. While data are collected in fine resolution strata (12 months, 21 subareas, 9 depth zones), the models are built for coarser resolution strata to account for uncertainty in combining dealer reports and port agent interviews. The 36 coarse spatio-temporal strata used in the models are: a) four state-area groupings of the 21 statistical subareas [Florida (FL): subareas 1-9; Alabama/Mississippi (AL/MS): subarea 10-12; Louisiana (LA): subareas 13-17; Texas (TX): subareas 18-21]; b) three groupings of the 9 depth zones (inshore, nearshore, and offshore waters); and three seasonal strata or trimesters (Jan-Apr, May-Aug, and Sept-Dec). Inshore waters are those internal to the International Regulations for Preventing Collisions at Sea 1972 (COLREGS) line. Nearshore waters are those extending from the COLREGS line to the 10-fm (18-m) isobath. Offshore waters are those beyond the 10-fm (18-m) isobath. Total fishery effort per stratum, in nominal days fished (i.e., total trawl bottom time divided by 24 hours), is modeled as the total shrimp catch divided by CPUE (see Nance 1992, Nance 2004, Nance et al. 2008 for full details). Shrimp fishery effort data include all three depth zones, while the Observer Program (next section) only covers nearshore and offshore waters.

In the inshore waters of the LA and AL/MS state areas, fishery effort estimates include effort from skimmer trawls and otter trawls. The Observer Program primarily places observers on otter trawl vessels, and the skimmer trawl fishery does not have enough observer coverage to estimate marine mammal bycatch. Therefore, we remove skimmer effort to yield stratified fishery effort estimates for commercial harvest from otter trawls only. Available effort data include stratified total fishery effort and stratified catch by weight apportioned to otter and skimmer trawls. Shrimp CPUE data stratified for skimmer and otter trawl gear are not available. Limited comparisons of otter and skimmer trawl CPUEs in North Carolina estuaries indicate high variability seasonally and by panaeid species caught (Coale et al. 1994), and CPUEs have been shown to vary spatially, temporally, and by species for both gear types in the Gulf of Mexico (Nance 1992, Coale et al. 1994, Nance 2004, Warner et al. 2004, Scott-Denton et al. 2006, Pulver et al. 2012). Since there was no systematic difference between CPUEs for the two gear types (Coale et al. 1994), we assumed equal CPUE for skimmer and otter trawls, and removed skimmer effort by multiplying the stratified total effort by the stratified proportion of catch by weight from otter trawls only to total catch (Table 2). Effort estimates in inshore LA and AL/MS strata may be biased if this assumption is invalid; implications of this assumption are considered further in the Discussion.

Observer Program Data

NMFS Gulf of Mexico Shrimp Trawl Observer Program data collection methods have been described in detail previously (Scott-Denton 2007, Scott-Denton et al. 2012). Briefly, in the Gulf of Mexico, NMFS-approved observers were placed on randomly selected shrimp vessels based on lists of federally permitted vessels which were active in the previous year. Random selection was based on the previous year of effort stratified by state area, depth zone, and season. The list of active vessels was derived from a cross-reference of NMFS shrimp landings files and US Coast Guard documentation records. Under the MSFCMA (MSFCMA; 16 USC1801), ESA, and MMPA, federal fishery permit holders are required to carry an observer if selected (MSFCMA § 303(b)(8)). Mandatory observer coverage compliance in the Gulf of Mexico shrimp trawl fishery has increased since 2007 as safety compliance by shrimp vessels has improved. For selected vessels, a minimum sea-day requirement of 18 days within a seasonal selection period was established to prevent potential early trip termination as a result of having an observer on board. A vessel may carry an observer for multiple trips to meet this minimum-sea-day requirement.

For each trip, a variety of vessel and gear characteristics are recorded, and for each tow, a variety of fishery-specific data is collected (See the observer manual, NMFS 2010, and Scott-Denton et al. 2012 for further details). The trip-level data used in bycatch analyses include number of observed tows and number of unobserved tows (unobserved tow data were available for 2007 – 2011, only). The tow-level data used in bycatch analyses include trip, date, time, location, depth, tow duration, number of nets towed, and number of mammals caught. Marine mammal bycatch documentation included information on the trip and tow in which bycatch occurred, number of animals, species identification, date, time, latitude, longitude, depth, gear entanglement location (e.g. TED net, lazy line), final disposition (e.g. dead/unresponsive, alive, unknown), and additional comments (Appendix B). Only data collected by the NMFS Observer Program for the Gulf of Mexico shrimp otter trawl fishery were used in these analyses. Data from the voluntary Foundation Observer Program (20.7% of tows), Atlantic shrimp trawl fishery (7.5% of tows), and skimmer and roller trawls (0.6% of tows) were not analyzed.

Analyses

Data Selection and Preparation

To prepare data for statistical analyses, all observed tows were assigned to one of the 36 fishery effort strata based on date, sub-area and depth at the start of the tow. Tows with missing values occurred occasionally; depth was the most frequently missed data value, with 776 (3.06%) tows missing out of 25,362 observed tows in Gulf waters. To reduce the amount of lost data, if depth at the start of the tow was missing, it was filled in, in order of precedence, with a) depth at the end of the tow, b) depth obtained from cross-referencing the ETOP01 one arc minute global relief model bathymetry data (Amante & Eakins 2009) for the latitude and longitude at the start of the tow, c) depth obtained from cross-referencing ETOP01 bathymetry data (Amante & Eakins 2009) for the latitude and longitude at the end of the tow, or d) remained missing if no additional information was available. The tows from the few observed trips with skimmer trawls (N = 92) and roller trawls (N=92) were removed, as were remaining tows with missing depth (N = 6) or year (N = 6) data.

Choice of Sampling Unit

The Gulf of Mexico shrimp trawl Observer Program follows a multi-stage random-sampling survey design. There are potentially three stages of sampling: vessel, trips within vessel, and tows within trips. For marine mammal bycatch, all tows are effectively observed, although approximately 5% of tows are not sampled with respect to quantifying fish bycatch. Therefore, the top level approximates a census, with zero variance, and yields a two-stage cluster design (Cochran 1977). This suggests the data are most appropriately analyzed as a two-stage cluster design with vessels as the primary stage and trips as units within vessels. However, total fishery effort is estimated as duration of tows, not as total trips per vessel. For this reason, we treat the study as a stratified random sample single-stage design, with trip, rather than vessel, as the unit of observation. Use of trip, rather than tow, as the analysis unit is likely more appropriate as it accounts for the lack of independence of tows within trips due to vessel/crew similarities and spatio-temporal auto-correlation of animal densities in spatio-temporally clustered tows (Cochran 1977). The potential problems of analyzing the data this way are that vessel variance and the variability in sampling probability among vessels are ignored. Vessels, not trips, were randomly sampled by the Observer Program stratified random sample design, so there is a potential bias in using trips as the unit of observation if these are not representative of the fleet.

Effort Definition and Adjustments

When calculating bycatch rate and total annual bycatch mortality, effort was defined as the duration of time that nets were in the water fishing. The number of nets towed was not included in the calculations because the total fishery effort estimate did not account for number of nets towed. Based on Observer Program data, vessels most frequently towed four nets (21,939 of sampled tows), with vessels towing two nets (2476 tows) or one net (157 tows) being sampled less frequently. Number of nets towed varied with depth stratum: fewer nets were towed in nearshore waters (3.21 $\pm$ 1.03 [mean $\pm$ st. dev.]) compared to offshore waters (3.95 $\pm$ 0.3 [mean $\pm$ st. dev.]; One-way ANOVA, n=1411 trips, F=396, p<0.0001), likely due to the tendency of smaller vessels, which tow fewer nets, to stay closer to shore. These results indicate that bycatch rate estimation under a stratified design accounts for differences in number of nets per tow across depth ranges. Linton (2012) estimated a mean of 3.0 nets per vessel for the entire fishery during 1997-2011, which includes skimmer vessels and those operating in inshore waters that are not sampled by the observer program. Skimmers only use two nets and vessels operating in inshore waters are likely to be smaller and use fewer nets, similar to the difference found between nearshore and offshore waters. The degree to which this accounts for the higher mean number of nets we find and whether this represents a bias toward sampling larger vessels remains unknown. Additionally, it remains unknown how the number of nets towed by a vessel impacts dolphin bycatch rates.

Observer Program bycatch and effort data were available per tow. To prepare these for analyses, tow data were aggregated into trips within strata such that trips were the unit of observation with observed hours fished and bycatch summed over all observed tows, and total hours fished per trip used as the effort variable. In some instances, trips were split if they occurred in multiple strata. While marine mammal bycatch is reported for all tows per trip, unobserved tows are only unobserved with respect to recording of fish bycatch and effort. Therefore, for trips with unobserved tows, the total documented effort per trip was lower than the actual effort while mammal bycatch was accurate. Data on the number of unobserved tows per trip were available for data collected between 2007-2011 and could be used to estimate total effort. Corrected effort per trip, $h_{corr,_l}$, was calculated as

$$h_{corr,_l} = (n_l + m_l)\ \frac{h_l}{n_l}$$

where $n_l$is the number of observed tows on the l^{th} trip, m_l is the number of unobserved tows on the l^{th} trip, and h_l is the total observed hours fished on the l^{th} trip.

Species Identification Scenarios and Final Disposition Status

During 1997-2011, all identified observed marine mammal takes were bottlenose dolphins, however, 7 takes were unidentified to species and may have been bottlenose dolphins or spotted dolphins. All unidentified takes occurred in ≥57 ft (17.3 m) waters and therefore cannot be confidently assigned to either species based on bathymetric distribution boundaries. To account for this uncertainty, bycatch rates are estimated under best-case and worst-case scenarios for bottlenose dolphin stocks and spotted dolphin stocks in which all unidentified dolphin takes are assigned to one species or the other. An alternative approach would be to assign takes based on relative densities of the two species; however, given uncertainty in how relative densities vary by season and differences in behavioral response to shrimp vessels by the two dolphin species, a density-based approach might give undue confidence in the resulting bycatch estimates.

The final disposition of several observed marine mammal takes led to questions on whether they should be included in bycatch mortality estimation. One marine mammal take observed during 1997-2011 was released alive with no evidence of serious injury (Angliss & DeMaster 1998) and was not included in bycatch mortality calculations. Non-lethal interactions are not considered further in this study, and the impact of these interactions on stock status is unknown. Three marine mammal takes were identified as decomposed animals with limited additional description of body condition and no supporting photographs. Without a necropsy, it is impossible to determine whether the animals were captured in this state or died in the net. Given the long duration of these tows (5, 11, and 13 hours) and lack of detail or photographs in observer and fisherman reports, these animals were included in bycatch mortality estimates. Each of these animals lacked species identification, so the best-case and worst-case scenarios still encompass the range of mortalities if any of the animals were captured in this state.

Stratified Bycatch Rate Estimation

The shrimp trawl fishery is such a large fishery (2007-2011 mean of 2.9 million hours actively fished per year) that the Observer Program, with current resources, can only cover about 0.5% of active fishing effort, and marine mammal bycatch is a relatively rare occurrence. Due to the relatively low level of observer effort and the low number of takes (12) observed during 1997-2011, a fully stratified bycatch rate estimate per year (24 strata by 15 years) is unreasonable, as most strata will have zero takes and may only sample a single fishing trip. To reduce the complexity of the models by collapsing strata, a four-way ANOVA was run comparing bycatch rates across strata to determine which strata were least variable, and hence, best to pool data over. Season and depth zone (nearshore and offshore) accounted for the greatest variability, while area and year accounted for the least variability. We anticipate that aggregation over years is less likely to impact bycatch rate estimation than aggregation over state areas. While interannual oceanographic variability, including the size and distribution of the

Gulf of Mexico hypoxic zone, could impact bycatch rates over time by influencing distribution of both fishing effort and dolphins, state area differences may be greater due to geographic habitat differences and differences in the fishery among states. Therefore, we base bycatch rate estimation on area-season-depth stratified data aggregated across 15 years. These 15 years include data from both the voluntary NMFS Observer Program (1997-2006) and the mandatory NMFS Observer Program (2007-2011) time periods. No significant differences in bycatch rates were found between these two periods (voluntary = 7.9E-5 takes/hour, mandatory = 8.1E-5 takes/hour; One-way ANOVA, n=1415 trips, F=0.06, p=0.81); therefore data from both periods were included in calculating bycatch rates to improve precision given the low number of observed takes. A separate analysis, conducted using data from the mandatory time period only, yielded similar total annual bycatch mortality estimates in which there were higher estimates with greater variances in those strata with observed bycatch and more strata with no observed bycatch. Given the historical record of takes within these strata, these zeros are likely due to limited observer effort rather than true absence of bycatch within these strata, and the bycatch rate estimates including 15 years of data in are thought to be more representative.

As described above, the relatively small number of observed takes (12) may not support bycatch estimation at the level of stratification available for observer program effort (24 strata), as zeros will occur in many strata. Therefore, in estimating dolphin stock annual bycatch mortality, two methods of bycatch rate stratification are compared to examine the trade-offs of accurately representing the sampling design (reduced bias) over pooling data (improved precision). The first method estimates semi-stratified (2 areas, 3 seasons, 2 depths) bycatch rates and applies them to fully stratified (4 areas, 3 seasons, 3 depths) effort data to obtain total annual bycatch mortality per stock[5]. In this case, the four state areas are combined into two larger regions of western Gulf (TX, LA, MS/AL) and eastern Gulf (FL). These regions are appropriate as they represent two major provinces with differences in oceanographic circulation, freshwater input, and benthic habitat characteristics (Gallaway 1981) that lead to differences in fishery

[5] The shrimp trawl Observer Program does not cover inshore waters; bycatch rates for nearshore strata were applied to the corresponding inshore strata. This method assumes that otter trawl bycatch rates are the same in coastal and inshore waters. The accuracy of this assumption will remain unknown unless Observer Program coverage can be extended into inshore waters.

target catch with brown and white shrimp targeted in the western Gulf and pink and rock shrimp targeted in the eastern Gulf. The second method estimates fully-stratified (4 areas, 3 seasons, 2 depths) bycatch ratios and applies them to fully stratified (4 areas, 3 seasons, 3 depths) effort data to obtain total annual bycatch mortality per stock[5]. This method accurately reflects the study sampling design.

For each of the stratification methods and species identification scenarios, stratified bycatch rates are estimated using the ratio of means method (Cochran 1977). This method weights longer duration trips more heavily than shorter duration trips and was selected under the assumption that long duration trips more accurately estimate catch rates of rare events than short duration trips.

The stratified bycatch rate, r_{ijk}, for the i^{th} area, j^{th} trimester, and k^{th} depth zone is calculated as

$$r_{ijk} = \frac{\sum_{l=1}^{n_{ijk}} y_{ijkl}}{\sum_{l=1}^{n_{ijk}} h_{ijkl}}$$

where n_{ijk}, y_{ijkl}, and h_{ijkl} are the number of observed trips, the total trip bycatch, and the corrected total hours fished per trip, respectively, on the l^{th} trip in the i^{th} area, j^{th} trimester, and k^{th} depth zone.

Stock Bycatch Mortality Estimation

To estimate annual bycatch mortality per bottlenose dolphin stock, strata were assigned to bottlenose dolphin stocks as follows: a) strata from all areas and seasons in offshore waters were assigned to the Continental Shelf stock; b) TX and LA area strata from all seasons in nearshore waters were assigned to the Western Coastal stock; c) AL/MS area strata from all seasons in nearshore waters were assigned to the Northern Coastal stock; d) FL area strata from all seasons in nearshore waters were assigned to the Eastern Coastal stock; e) inshore strata were limited to state area resolution and seasonal strata were aggregated per state area and assigned to aggregated BSE stocks for each state (Table 3, Figure 1). For spotted dolphins, all offshore and nearshore strata were aggregated. Overall, the fishery strata boundaries match the dolphin stock boundaries well, with the exception of the AL/MS to FL state boundary and the 84°W boundary between the Eastern Coastal and Northern Coastal bottlenose dolphin stocks. The Northern Coastal stock range is underestimated and the Eastern Coastal stock range is overestimated. Similarly, state area boundaries for inshore waters do not provide the resolution needed to assign bycatch to individual BSE stocks.

To obtain annual bycatch mortality, we multiply the stratified bycatch rates by annual stratified effort estimates to obtain stratified bycatch mortality estimates. We then combine these estimates over the appropriate strata to obtain annual bycatch mortality estimates per stock. The stratified estimator of the total annual bycatch mortality per stock is calculated as

$$\hat{\tau}_{stock} = \sum_{i}\sum_{j}\sum_{k} M_{ijk} r_{ijk}$$

where M_{ijk} is the total hours fished in the i^{th} area, j^{th} trimester, and k^{th} depth zone summed over areas and depth zones that fall within each stock's boundaries (Table 3).

Five-year Mean Annual Bycatch Mortality Estimate

Following the Guidelines for Assessing Marine Mammal Stocks (GAMMS) (Wade & Angliss 1997), the unweighted means of the last five years' annual bycatch mortality estimates were calculated using 2007-2011 annual stock bycatch mortality estimates.

Coefficients of Variation and Confidence Intervals

Bias corrected and accelerated (BCa) bootstrapping techniques were used to derive the confidence intervals (CIs) and standard bootstrapping techniques were used to derive the coefficients of variation (CV) for the bycatch mortality estimates for each stock. As with bycatch rate estimation, the re- sampling unit used was an entire trip rather than an individual tow to ensure that any within-trip dependence was carried over into the estimated CV.

Comparison with Potential Biological Removal

The estimated annual stock bycatch mortalities are compared against the allowable mortalities determined by PBR from the most recent stock assessment report (SAR) (Table 1, Waring et al. 2014, Waring et al. 2015 in review). The 2014 draft SAR reports best abundance

(N_{best}) estimates and CVs for each stock, but only provides minimum abundance (N_{min}, used to calculate PBR) and PBR for stocks when abundance estimates are less than 8 years old (Waring et al. 2014, 2015 in review). Wade and Angliss (1997) recommend that N_{min} values older than 8 years not be used in the calculation of PBR values as they are unreliable. Unfortunately, these values have expired for most Gulf of Mexico bottlenose dolphin BSE stocks. However, for our analyses, the last available values are included in our comparison, even though they may have expired. This is only to give a general scale of where bycatch mortality may fall with respect to stock abundance, and updated N_{min} and PBR values are required to accurately represent any impact of the fishery on these stocks. For stocks with expired estimates, minimum abundance was calculated as $N_{min} = {N_{best}}/{C}$, where $C = e^{\left(z_{1/2\alpha} * \sqrt{\log(1+CV^2)}\right)}$, $\alpha = 0.4$, and $z_{1/2\alpha}$= 0.842. Then, PBR was calculated as $PBR = N_{min} * 0.5 * R_{max} * F_r$, where R_{max} = 0.04, and F_r =0.5, (Wade & Angliss 1997). Some BSE stocks have abundance estimates of 0 due to limited survey effort (Sabine Lake, Calcasieu Lake, Vermilion Bay, West Cote Blanche Bay, Atchafalaya Bay, Perdido Bay, and Caloosahatchee River; Appendix C). The abundances for these stocks are likely higher than zero; therefore, calculated N_{min} and PBR values are underestimates. As shrimp fishery effort resolution is not fine-scale enough to assign dolphin takes to a given BSE stock, a minimum N_{min} and PBR (the lowest N_{min} and PBR of all BSE stocks within the state area), a maximum N_{min} and PBR (the highest N_{min} and PBR of all BSE stocks within the state area), and an aggregate N_{min} and PBR (the sum total of N_{min}s and PBRs for all BSE stocks within the state area) are included for state area BSE aggregations. The minimum BSE PBR provides a conservative estimate in the event that all takes are from a single stock with low abundance, while the maximum BSE PBR provides an estimate if all takes are from a single stock with the highest abundance, and the aggregate BSE PBR provides an estimate if all stocks are proportionally affected by bycatch mortalities.

Vessel, Gear, and Tow Operation Characteristics

In an effort to understand how vessel operations may affect bycatch risk, comparisons are made of vessel, gear, and operating characteristics of tows or trips with and without marine mammal bycatch incidents. Vessel and gear characteristics are analyzed at the trip level, while operating characteristics are analyzed at the tow level, as these will vary within a trip. Analyzed vessel characteristics include vessel length, gross tonnage, engine HP, year built, crew size, construction type and cold storage type. Comparisons with bycatch events included all observed marine mammal takes from 1997-2011. Gear characteristics reported by observers include information on trawl nets, BRDs and TEDs (see Appendix A, and Maiolo 2004 for detailed gear description). We analyzed headrope and footrope lengths, trawl net mesh size, trawl net material, lazy line rigging, and a variety of TED characteristics including type, design, opening location, funnel occurrence, flap occurrence, construction material, float type, float shape, angle, width, and length. Gear characteristics were reported for most nets on several, but not all, tows per trip. Gear usage was generally consistent within a trip, though some variation existed across nets and tows. For numeric gear characteristics, we summarize gear by the minimum, maximum, and mean values per trip. For class gear characteristics, we summarize gear by the modal value per trip. Statistical comparisons between bycatch and non-bycatch trips included all bycatch events occurring during 1997-2011 for general gear characteristics, but only trips with lazy line bycatch or TED net bycatch for lazy line and TED characteristics, respectively. Operating characteristics analyzed per tow were vessel speed, tow duration, sea state, time of day, and net retrieval direction. Statistical comparisons with bycatch events included all observed marine mammal takes. Statistical comparisons were made using Matlab software. Characteristics with numeric metrics were compared using one-way unbalanced ANOVA tests (Zar 1999). Characteristics with class metrics were compared using two-sample Kolmogorov-Smirnov tests (Zar 1999). Time of day was compared using a Watson-Williams test, a circular statistic equivalent to a one-way ANOVA (Zar 1999, Berens 2009).

RESULTS AND DISCUSSION

Fishery Effort

From January 1997 through December 2011, annual effort in the Gulf of Mexico shrimp trawl fishery showed a general decline with a peak effort of 304,639 nominal days fished in 2002 (274,242 nominal days fished in 1997 for otter gear only), compared to a minimum effort of 106,886 (83,895 for otter gear only) nominal days fished in 2008 (Figure 2). Percentage of annual effort with respect to state area and season varied little over time, while percentage of effort in inshore waters increased over time (Figure 3). Geographically, the greatest effort occurred off LA (50%), followed by TX (25%) and seasonally, the most effort occurs between

May – December (85%). By depth, most effort took place in offshore waters (> 10 fathoms, 35%), followed by inshore waters and nearshore waters, with effort in inshore waters increasing over time (up from 25% to 45%) (Figure 3).

Observer Program Effort

Between January 1997 and December 2011, a total of 790 trips and 305 unique vessels were observed by the NMFS Gulf of Mexico shrimp otter trawl fishery Observer Program, which includes periods of voluntary and mandatory coverage. This represents only trips with complete observation data available (some data were removed due to missing year, missing depth, skimmer gear, non-NMFS program, and Atlantic location). During the 1997-2006 voluntary coverage period, 368 trips and 69 unique vessels were observed, with a mean of 5.3 trips per vessel. During the 2007-2011 mandatory coverage period, 422 trips and 247 unique vessels were observed, with a mean of 1.7 trips per vessel. Repeated observation of vessels during the mandatory coverage period is mainly due to multiple observed trips per vessel to reach the 18-day minimum requirement for observer placement. For stratified analyses of bycatch rate, the 790 trips yielded a total of 1415 trip*strata observations, as trips frequently crossed strata (years, seasons, depths, states), covering, on average, 1.79 strata per trip. In total, 25,160 tows were observed for a total of 5502.2 nominal days fished. An additional 965 tows were unobserved between 2007 and 2011, yielding an estimated 5714.6 nominal days fished. Mean annual observed effort was 0.24 $\pm$0.21 % of total fishery effort from 1997 to 2011 (Figure 2). Coverage of the fishery by the Observer Program has increased over time from 0.12 $\pm$ 0.10 % of fishery effort in the voluntary coverage period from 1997-2006 to 0.48 $\pm$ 0.14 % fishery effort in the mandatory coverage period during 2007-2011 (Figure 2).

The proportional coverage of each stratum by the Observer Program is highly variable from year to year (Figure 3). When aggregated over all 15 years, there are many similarities in the proportional coverage of stratified effort of the total fishery and the Observer Program, with some notable differences (Figure 3). Compared to shrimp fishery effort, the Observer Program has disproportionately more coverage 1) in the TX area; 2) during winter, and 3) in the offshore waters. Conversely, Observer Program coverage is disproportionately low 1) in the LA area; 2) during summer; and 3) in inshore and nearshore waters. The depth effect is stronger in early years and decreases over time, likely as an effect of mandatory coverage and improvements in safety compliance on smaller vessels, which typically work shallower, nearshore waters. A major limitation is that the Observer Program does not attempt to cover inshore waters, which represent up to 45% of annual effort from the fishery. A comparison of the geographical distribution of Observer Program effort by season (Figure 4) reveals that it is higher off FL in winter and off LA and TX during summer and fall trimesters, which is representative of what is known of fishery effort as a whole. Since seasonal selection periods were used by the Observer Program for vessel selection, we plotted histograms of the distribution of Observer Program effort across months and visually examined them to ensure effort was not skewed toward the early part of each season.

Observed Marine Mammal Interactions

A total of 14 marine mammal interactions were observed by the Observer Program between 1993 and the first season of 2012, with 12 of those occurring within this study's bycatch rate estimation period from 1997 to 2011 (Table 4, Figure 5). Of these 12 animals, 5 were identified as bottlenose dolphins, with the remaining 7 identified as either unidentified dolphin or marine mammal. The majority of takes occurred during the Jan-Apr season (six) followed by the Sep-Dec season (five) with a single entanglement during the May-Aug season. Most takes occurred off TX (four) and LA (four), and in offshore ($\geq$10 fathom) waters (seven) (Figure 6). Six entanglement events occurred in the lazy line, followed by 5 entanglements in TED nets. A single entanglement occurred in the tickler chain. Dolphin condition on entanglement included released alive (one), fresh dead (five), decomposed (three), and unknown/not given (three). Of those classified as decomposed, one was identified as a dolphin carcass and accounts for the tickler chain entanglement. The two other entanglements identified as decomposed were entangled in the TED nets, and tow durations for these events ranged between 5-13 hours. These animals may have been captured in this state, but this cannot be confirmed without a necropsy, and no further documentation was available to elucidate time of death. The animal that was released alive is not considered as a Mortality or Serious Injury (MSI) for this study and was removed from bycatch mortality analyses. This animal accounts for the single May-Aug entanglement event.

Vessels, Gear, and Tow Operation Characteristics

Vessel characteristics reported by observers include vessel length, gross tonnage, engine HP, year built, crew size, construction type and cold storage. From 1997 to 2011, per trip, the mean vessel length was 73.8 ± 10.8 ft (range: 33-98). The mean gross tonnage ranged from 10 to 213 tons with a mean of 124.6 ± 36.7 tons and the mean engine HP ranged from 85 to 1234 with a mean of 532.4 ± 209.3. Vessels were built between 1951 and 2003, with a mean year built of 1986 ± 10.4. Vessel crew size ranged between 0 and 4 crew members with a mean of 2.40 ± 0.68 people. The majority of trips were on vessels constructed from steel (87.5%), followed by fiberglass (8.6%), wood (2.9%), and mixed fiberglass/wood (0.9%). The majority of trips were on vessels with freezers (65.1%) followed by ice cooling (16.2%), and 18.7% with unknown cold storage. There are no significant differences in vessel characteristics with respect to trips with dolphin takes compared to trips with no observed takes (One-way ANOVA, alpha = 0.05: vessel length, gross tonnage, engine HP, year built, crew size; Two-sample Kolmogorov-Smirnov test: construction material, cold storage), though small differences would be difficult to detect given the relatively small number of observed takes.

Gear characteristics reported by observers include information on trawl nets, BRDs and TEDs. Headrope and footrope lengths ranged between 20.3’ and 81.5’ with mean lengths of 47.8 ± 9.7’ and 55.8 ± 10.8’, respectively. Trawl net mesh sizes ranged between 0.75” and 2.38” with mean 1.75 ± 0.3”. TED angles ranged between 18 and 87^{o} with a mean angle of 50.2 ± 7.5^{o}. TED lengths ranged between 10”-67” (mean 46.4 ± 5.3”) and widths ranged between 30” and 59” (mean 38.2 ± 3.6”). Dolphin bycatch in TED nets occurred on trips with significantly narrower TED widths (range: 32-40”, mean 34.7 ± 1.9”, ANOVA: n=776, F=3.97, p=0.047; Note, in 2003, NMFS issued a final rule, 68 FR 8456, requiring use of larger TEDs with minimum widths of 44” in inshore waters and 71” in offshore waters). Other gear characteristics did not have significant differences between trips with no observed takes and trips with dolphin bycatch. For 790 trips, the majority of lazy lines were rigged with elephant ears (98.1%), followed by choke (1.6%) and unknown. The majority of TED types were hard (99.7%), with small numbers of soft, unknown and none. TED designs included: curved bar (77.9%), straight (20.2%), weedless (1.0%), unknown and none. The majority of TED openings were on the bottom (76.0%), followed by top (23.6%), then unknown and none. Trawl material was mainly nylon (63.3%) followed by spectra (15.8%) and sapphire (14.3%) with small numbers of other, unknown, and poly. The majority of TEDs did not have funnels (79.3%) and did have flaps (93.5%). The majority of TEDS were made of aluminum (96.4%) followed by steel (2.5%), with small numbers of unknown, none, mesh and other. The majority of TED float types were of foam (50.8%) or plastic (32.5%) (others included hard foam, unknown, other, multiple, hard plastic, none, sponge, and cork) while the majority of float shapes were football (39.5%) and round (27.3%) (others included unknown, bullet, other, multiple, none, and cylinder). Statistical comparisons in gear use were made between trips with dolphin takes and those with no dolphin takes; for TED gear and lazy line gear comparisons, only trips with dolphin takes involving entanglement in that particular gear type were included as positive for dolphin takes. There were no significant differences in these gear characteristics with respect to trips with dolphin takes compared to trips with no dolphin takes (Two-sample Kolmogorov-Smirnov test, alpha = 0.05; Appendix D1-2), though small differences would be difficult to detect given the relatively small number of observed takes.

Operating characteristics of individual tows were also compared for observed tows with dolphin bycatch (N=9) compared to those without (N=25148; Appendix D3). There were no significant differences between vessel speed for all tows (range: 0.4 - 4.6, mean ± stdev, 2.85 ± 0.24) and tows with dolphin bycatch (2.6 - 3.2, 2.92 ± 0.19; One-way ANOVA: n=24,981 tows, F= 0.83, p=0.36). Similarly no significant differences existed between sea state for all tows (1 - 4, 1.63 ± 0.77) and tows with dolphin bycatch (1 - 3, 1.67 ± 0.87; One-way ANOVA: n=24,932 tows, F= 0.02, p=0.89). Tow durations (hours) were significantly higher for tows with dolphins (4.6 - 13.2, 7.1 ± 2.95) compared to all tows (0 - 16.7, 5.25 ± 2.06; One-way ANOVA: n=25,133 tows, F=7.23, p=0.007). The effect of time of day was also significant, with the midpoint of tows with dolphin bycatch (circular mean ± stdev: 07:00 ± 2.73 h) occurring later in the day than the midpoint of tows without dolphin bycatch (circular mean ± stdev: 05:12 ± 2.0 h; Watson-Williams: n=25,148 tows, F=8.81, p=0.003). This may reflect diel differences in dolphin behavior or observers' inability to observe a marine mammal bycatch event in darkness. For 25,151 tows without dolphin bycatch, nets were retrieved cross sea (25.2%), down sea (13.5%), up sea (59.9%) and unknown (1.5%) and for 9 tows with dolphin bycatch, nets were retrieved cross sea (22.2%), down sea (33.3%), and up sea (44.4%). These differences were not significant (2-sample Kolmogorov-Smirnov test n=25,151, p=0.94, k=1.17). These comparisons of operating characteristics during individual tows assume that tows within trips are independent; it is unknown whether one-way ANOVAs are robust to deviations from this assumption (Zar 1999). Sea state comparison tests may violate this assumption as consecutive tows within trips may have similar sea state characteristics. The independence of vessel speed tow duration, time of day, and net retrieval direction among tows within trips is unknown.

Bycatch Rate and Bycatch Mortality Estimates

The effort, bycatch rate, and annual bycatch mortality estimates for marine mammal stocks from each of the two stratification methods and two species scenarios are presented in Appendix E, and the 2007-2011 five-year unweighted mean annual total bycatch mortality estimates are presented for each bottlenose and spotted dolphin stock in Table 5. Bottlenose dolphin bycatch mortality estimates in shrimp trawls from the LA BSE and AL/MS BSE stocks are well above the last estimated PBR, regardless of stratification method used or best-case and worst-case scenario for incorporating unidentified dolphins (Table 5, Figure 7). Depending on the method used, bycatch mortality estimates of TX BSE bottlenose dolphin stocks may also be above the last estimated PBR, and are likely above 10% of PBR. Bottlenose dolphin bycatch mortality estimates of Northern Coastal and Western coastal stocks are above 10% of PBR in all scenarios, but are unlikely above PBR. Similarly, the bycatch mortality estimates of the spotted dolphin stock and the bottlenose dolphin FL BSE stocks are above 10% of the last estimated PBRs, in the respective worst-case scenarios for incorporating unidentified dolphins. If all bycatch comes from a single or few stocks, the bycatch mortality estimates of FL BSE bottlenose dolphin stocks may be greater than 10% or 100% of the last estimated PBR, depending on stock affected and analysis method. For all methods and best and worst case scenarios, bycatch mortality estimates for Eastern Coastal and Continental Shelf bottlenose dolphin stocks are under 10% of PBR.

As model stratification increases, bycatch mortality estimates for nearly all dolphin stocks increase with corresponding increases in uncertainty. The exceptions are the Western Coastal and TX BSE stocks when all unidentified dolphins are ID'd as bottlenose dolphins, and spotted dolphins when all unidentified dolphins are ID'd as spotted dolphins. This results from high bycatch rates for AL/MS and LA nearshore winter strata in which there were two bycaught animals and relatively lower Observer Program effort. With lower levels of stratification, these catches are "spread out" over greater effort coverage, hence decreasing the estimated catch in LA and AL/MS nearshore regions and increasing catch in the TX nearshore region.

Count data are often well approximated by a Poisson distribution, in which the mean is equal to the variance ($\mu = \sigma^2$). However, bycatch surveys typically contain a large proportion of zero observations, resulting in highly skewed sample distributions that may be better approximated by a delta log-normal distribution (e.g. Pennington 1983). In comparing bootstrap distributions across the two methods, the semi-stratified method distributions more closely approximate a Poisson distribution than the fully-stratified method, which had more highly skewed distributions. It is unknown whether bycatch rates vary by state area rather than oceanographic regime and hence is difficult to support one method over another.

Sources of Bias and Uncertainty

Port agent assignment of location

Due to the large size of the Gulf of Mexico shrimp trawl fishery, effort could not be quantified directly and was modeled for each statistical area based on landings allocations from either the best available data (from non-random interviews with a sample of the fleet) or judgment drawn from the agent's understanding of the fishing pattern of the local fleet (Nance 1992). Misallocation of landings to statistical area and depth cells may lead to biased estimates of effort for each depth/area stratum and thus affect bycatch estimation. Gallaway et al. (2003) examined whether there was a directional bias to shrimp CPUE estimates based on port agent data by comparing to actual locations fished as determined by an experimental electronic logbook program. In particular, they found modeled effort to be higher in 10-30 fathom waters off Texas and lower in the adjacent nearshore and deeper waters. Their study compared locations to finer resolution strata than are described here, and the aggregation into lower-resolution strata may reduce this bias somewhat. In particular, the deeper waters and midshelf waters they described fall into the same depth zone in this study, which corresponds to the range for the Continental Shelf stock of bottlenose dolphins. The increased effort in one zone may therefore balance the decrease in the other. However, this does not account for the missed effort in nearshore waters, and suggests it is likely that our bycatch mortality estimate for the Western Coastal stock of bottlenose dolphins (which is already over PBR) may be biased low.

Incorporation of electronic logbook data into effort estimation since 2006 (Nance et al. 2008) has reduced this bias.

Observer Program distribution

The majority of Observer Program effort has occurred in nearshore and offshore waters with extremely limited effort in inshore waters. This represents a major limitation of this study, as annual effort in inshore waters may be as high as 45% of the total fishery effort. The stratified bycatch mortality estimates calculated for inshore waters rely on stratified bycatch rates estimated for nearshore waters, under the assumption that these will be similar. Dolphin densities, behavioral responses to shrimp boats, and shrimp boat gear and operations may differ between these areas which could result in different bycatch rates between nearshore and inshore waters. These differences may result in biased bycatch mortality estimates for inshore waters, but the direction and degree of this bias is completely unknown. While this bycatch rate extrapolation approach is more reasonable than assuming no bycatch mortalities occur in inshore waters, the expansion of observer program effort into inshore waters is necessary to accurately estimate bycatch mortality of BSE dolphin stocks.

Non-federal effort, vessel differences, and non-commercial effort

Another source of bias in Gulf of Mexico shrimp trawl fishery Observer Program comes from the exclusion of non-federally permitted vessels in the Observer Program data, but not the effort data, and the resultant assumption that dolphin bycatch mortality rates are not significantly different between federally permitted and non-federally permitted vessels. Only commercial shrimp fishery vessels which fish in federal waters are required to obtain a federal permit; historically, the Observer Program has only placed observers on federally permitted vessels and, hence, vessels which only fished within state territorial waters were not observed. While bycatch rates were assumed to be similar in nearshore and inshore waters, vessel-specific differences between federally and state regulated vessels may occur; in particular, vessels fishing nearshore state-waters may be smaller and tow fewer nets for shorter durations than those observed. If smaller vessels had lower mammal bycatch rates, as has been suggested for turtles (Epperly et al. 2002), bycatch mortality estimates might be biased high in inshore waters. The degree of this bias may vary from state to state due to differences in regulations and differences in the extent of waters encompassed within their territorial boundaries. The boundary between state territorial and EEZ waters varies by state, with state territorial waters wider off FL and Texas (9 nmi from shore) and narrower off LA, AL, MS (3 nmi from shore), so this bias may be stronger off Florida and Texas. However, the effect of vessel size, speed, and number of nets towed on mammal bycatch rates is completely unknown.

Additionally, effort data only include the commercial sector landing table shrimp. They do not include shrimp harvested by recreational fishermen, small-scale commercial fishermen that sell their catches along roadsides (Poffenberger 1991), or those caught for use as bait. While this effort may be substantial, it is unknown whether it results in marine mammal bycatch as these fishermen are restricted to using a small amount of gear in inshore waters. If this non-commercial effort results in marine mammal bycatch mortalities, the presented bycatch mortality estimates for the BSE stocks may be biased low.

Skimmers effort

Whether there are interactions of marine mammals with commercial skimmer trawls is unknown and therefore skimmer trawl effort is not included in these bycatch mortality estimates. There has been limited Observer Program coverage of commercial skimmer trawls (about 1500 hours) and zero observed takes (Scott-Denton et al. 2006, Pulver et al. 2012, ESD unpublished data). One bycaught marine mammal is observed for every 12,500 hours of otter trawl fishing, so there have not yet been enough data collected to determine whether this is a concern for commercial skimmers. However, gear and operating characteristics differ significantly between the two fishing practices. These differences reduce the likelihood of fatal interactions for sea turtles: a) the nets are smaller and are actively pushed through the water rather than passively towed, b) they are towed close to, or at, the surface, and c) skimmers are limited to <1 hour tow durations to reduce fatalities from sea turtle interactions (but the level of fishery compliance with the tow time limitation is unknown) (Scott-Denton et al. 2006). It is unknown whether these differences would also lead to reduced fatalities from marine mammal interactions with skimmers. The active, near surface, short duration fishing methods used during skimmer operations may result in interactions of a mammal with gear being more likely to be observed quickly and released before serious injury or mortality can occur, as has been found for turtles. Since 2013, two bycatch interactions have been observed in a research skimmer trawl, one in which the animal was released alive and in good condition, and one resulting in mortality (Pers. comm. Keith Mullin, NOAA Fisheries, SEFSC). Whether commercial skimmer bycatch mortality presents a problem for marine mammals will remain unknown until the Observer Program has greater coverage of this section of the fishery. Skimmer trawls are legal in the inshore waters of only the LA and AL/MS state areas, and may represent up to 20% of annual shrimp fishery effort. If MSI interactions occur, these are currently unaccounted for and the LA BSE and AL/MS BSE stock bycatch mortality estimates would be biased low. Additionally, an assumption was made when removing skimmer trawls from inshore effort that shrimp CPUE is equivalent between otter and skimmer trawls. Coale et al. (1994) found higher white shrimp CPUEs and lower brown shrimp CPUEs for skimmer trawls. If total shrimp CPUEs vary, inshore LA and AL/MS effort from otter trawls may be affected, leading to biased bycatch mortality estimates for the LA BSE and AL/MS BSE stocks.

Species and Stock Identifications

The assignment of species ID to unidentified marine mammal takes is a source of uncertainty. We attempted to put bounds on this by estimating best-case and worst-case scenarios for each species, while the true values likely lie somewhere in between. Four of seven unidentified dolphins occurred on either side of the boundary between nearshore and offshore waters. While spotted dolphins likely spend the majority of their time in offshore waters, they have been sighted in shallower waters and seasonal inshore movements have been described (Fulling et al. 2003, Griffin & Griffin 2003). Therefore, effort from nearshore waters is included in the bycatch mortality estimates for this stock. During the 1980s in the Gulf of Mexico, several spotted dolphins were documented as bycatch (Fertl & Leatherwood 1997) and spotted dolphin foraging in association with shrimp vessels has also been described (Delgado Estrella 1997, Fertl & Leatherwood 1997). Nevertheless, spotted dolphins have never been documented by the Observer Program among marine mammal bycatch in the shrimp trawl fishery (two spotted dolphin mortalities have occurred in research trawls, one in the southeastern US Atlantic and one in the Gulf of Mexico). Based on known distribution and no positive identifications by the Observer Program, bycatch mortality estimates developed under the scenario in which all unidentified delphinids are assigned to spotted dolphins are likely biased high for spotted dolphins. Similarly, given the lack of documented spotted dolphin takes, the worst-case scenario bottlenose dolphin estimates (all unidentified delphinids are assigned to bottlenose dolphin) are probably more accurate, particularly in western waters where spotted dolphin abundance is lower. We anticipate this source of uncertainty will be reduced for future bycatch mortality estimates as species identification rates have improved in recent years with 17% of takes classified to species prior to 2007 and 63% classified to species since 2007. Obtaining photographs and tissue samples for genetic studies would further help to improve species identification.

The current Gulf of Mexico bottlenose dolphin stock boundaries are close to the strata defined for the shrimp trawl fishery. Three notable deviations include 1) the location of the Northern Coastal/Eastern Coastal stock boundaries and the FL vs AL/MS state area boundary, 2) the grouping of all BSE stocks within a state due to lack of finer resolution effort data and 3) limited knowledge of population boundaries and seasonal movements. For the first case, where there are differences in the coastal bottlenose dolphin stock boundaries and state area effort boundaries, bycatch mortality estimates for the Northern Coastal stock may be biased low while those of the Eastern Coastal stock may be biased high as effort from 84°W to 87°W is misallocated to the Eastern Coastal stock. For the second case, to better understand the potential impact of a grouped state area bycatch mortality estimate on the multiple BSE stocks found within the state area, bycatch mortality estimates are compared to both a minimum and maximum PBR where the minimum refers to the minimum PBR of any BSE stock within the state area and the maximum PBR represents the sum PBR of all BSE stocks within the state area. It is possible that all takes could come from a single stock, and using the minimum PBR is a conservative method of determining impact. Conversely, when takes exceed the maximum PBR, there is no question that the fishery is having a significant impact on at least one, if not all, BSE stocks within that state. For the third case, considering seasonal movements and stock boundaries, we have used the best available science to assign takes and bycatch mortality estimates to the appropriate stock. These may need to be revised as genetic studies better inform us of population boundaries or as we learn more about the seasonal movement patterns of each stock.

Stock abundance estimates, and the resulting N_{min} and PBR calculations, are older than 8 years for most Gulf of Mexico bottlenose dolphin BSE stocks and the Atlantic spotted dolphin stock (Waring et al. 2014, 2015 in review). This results in a high degree of uncertainty in the status of these stocks and what levels of shrimp fishery bycatch mortality they can sustain. If a stock's population size were declining at 10% per year, the worst decline seen for a marine mammal species, stock abundance could be reduced by 50% over an 8 year period (Wade and Angliss 1997) and the number of bycatch mortalities it could sustain would be significantly lower. Ideally, this uncertainty would be resolved with new abundance surveys to provide reliable stock abundance and PBR estimates. Recent ship surveys have been conducted in the Gulf of Mexico, and updated abundance estimates are expected for the Northern Gulf of Mexico Atlantic spotted dolphin stock in the 2014 Stock Assessment Reports. Recent aerial survey and photo-identification mark-recapture surveys have been conducted for some Gulf of Mexico BSE stocks and updated abundance estimates are being calculated for the Barataria Bay, LA stock as well. Abundance estimates for most of the remaining BSE stocks are expired resulting in high uncertainty in assessing the impact of the estimated bycatch rates. Updated abundance estimates are particularly important for stocks affected by the ongoing Northern Gulf of Mexico UME as these stocks' distributions overlap regions of high fishery effort and have subsequently high bycatch mortality estimates.

Mortality and Serious Injury Classification

One bycatch incident in which the animal was released alive was excluded from bycatch mortality estimation. Observer comments indicated that the animal was entangled in the lazy line, the line was cut, the animal was released alive and appeared in good condition with no noticeable injuries. While we chose not to include this take as a serious injury for these analyses, it is possible this entanglement led to subsequent mortality. Depending on the duration and location of the entanglement, the animal may have 1) suffered capture myopathy leading to compromised health if it did not have regular access to oxygen or food for an extended period of time (Andersen et al. 2008, NMFS 2012), 2) suffered serious internal injuries not evident to the observers, or 3) been separated from its social group with potential for increased stress, decreased foraging success, or increased predation risk if it was unable to locate its conspecifics (Angliss and DeMaster 1998). If we misclassified this bycatch incident and it should have been MSI, our bycatch mortality estimates will be biased low.

Variance

There are a number of sources of variance uncertainty in these bycatch mortality estimates that could not be accounted for. First, fishery effort was estimated from models (Nance 1992, Nance 2004), but no estimate of uncertainty was available for inclusion in the bycatch variance estimates. Second, the three methods here used trip as the unit of observation and did not account for the two-stage design, which should include both variance among trips within vessels and variance among vessels. The within vessel variance is unknown. Next, we chose to leave nets out of the equation when calculating effort. There was some variability in the number of nets towed between trips, and variance will therefore be biased low. The degree of bias is expected to be greater for nearshore and inshore waters where the number of nets towed was lower and more variable. Lastly, unobserved tows may have been incorrectly assigned when trips are split across strata. Unobserved tows are only noted per trip, not per stratum within a trip, and were assigned to the stratum of the last tow. This could have affected the variance for bycatch as well as the total Observer Program effort within a stratum. For trips with documented mammal bycatch, only 2 of 7 takes (since 2007) occurred on trips that both fished over multiple strata and had unobserved tows. One trip had unobserved tows in the same stratum as the bycatch occurred and one had bycatch and unobserved tows in different strata. These effects are probably random and non-directional in nature so that bycatch mortality estimates and variances are not biased.

An additional source of bias and uncertainty is the inclusion of 1997-2006 Observer Program data. Data collection during this period was non-random due to the voluntary nature of the program during this time. The variance calculations may have been biased due to differences in trip selection probability in pre-2007 years; however, this bias is expected to be small compared to the improvements in estimation realized by including more years of data for a dataset with such a high quantity of zeros. Trip-level bycatch rates were not significantly different between years grouped as pre-2007 and post-2006.

To obtain representative annual bycatch mortality estimates for marine mammal stocks, the unweighted 5-year-mean bycatch estimates were calculated from the 2007-2011 annual bycatch mortality estimates as recommended in the GAMMS guidelines (Wade & Angliss 1997).

These are the first 5-year-mean bycatch mortality estimates for the Gulf of Mexico shrimp trawl fishery and the historical impact of this fishery on dolphin stocks is unknown. Gulf of Mexico shrimp trawl fishery effort has been declining over the last 15 years and the percentage of Observer Program coverage has been increasing; however, there is no significant difference in bycatch rates between early years and later years. Calculations of historical catch estimates are included (Appendix E) and in many cases greatly exceed bycatch mortality estimates for 2007-2011 due to the higher effort. The long term impact of historically high catch rates on these dolphin stocks is unknown, but the stocks have likely benefitted from declines in fishery effort.

SUMMARY AND CONCLUSION

This report presents the first estimates of total annual bycatch mortality of marine mammals in the Gulf of Mexico shrimp otter trawl fishery. While Observer Program coverage is generally low, there is still a substantial quantity of data available for marine mammal bycatch mortality estimation. Two stratification methods were considered along with two scenarios to account for unidentified marine mammal species catch, and in all cases, the total annual bycatch estimates are above 10% of PBR for Western Coastal and Northern Coastal bottlenose dolphin stocks. It is possible that the PBR threshold has been exceeded for LA BSE and AL/MS BSE bottlenose dolphin stocks, though further data on both abundance and bycatch rates in inshore waters are required to determine whether this has occurred. Other stocks which may be at risk from shrimp otter trawl fishery bycatch include the TX BSE and FL BSE bottlenose dolphin stocks and the Atlantic spotted dolphin stock, while the Eastern Coastal and Continental Shelf bottlenose dolphin stocks are at lower risk and approaching the zero mortality rate goal (i.e., under 10% PBR).

The greatest sources of error and bias in bycatch mortality estimates come from inadequate knowledge of both the fishery and the stocks it impacts including: 1) distribution of fishery effort in inshore waters, 2) bycatch rates of dolphins in inshore waters, 3) stock abundance, particularly in inshore waters, and 4) whether skimmer trawls and non-commercial fisherman catch dolphins. As much as 45% of annual shrimp fishery effort occurs in inshore waters, with the majority occurring in Louisiana (up to 33% of annual effort), and this is an area with the least information available. Several sources of information could improve our knowledge and will help reduce the uncertainty in the bycatch mortality estimates presented in this report. Observer Program coverage of inshore waters, including non-federally permitted vessels and skimmer trawls, would provide information on bycatch rates and could be used to estimate the distribution of fishery effort within these waters. Assuming similar bycatch rates to nearshore and offshore otter trawls, approximately 12,500 hours of active fishing effort must be observed to observe one dolphin take. Distribution of fishery effort could also be obtained if electronic logbooks could be placed on both federally-permitted and non-federally-permitted vessels operating in inshore waters. Improved knowledge of fishery distribution in inshore waters from either Observer Program coverage or electronic logbook data could then be used to prorate bycatch rates to individual BSE stocks. Additionally, genetic and photographic sampling of bycaught dolphins may improve stock identification. If advanced genetic techniques are developed to differentiate individual bottlenose dolphins at the stock level, tissue samples could be obtained by the Observer Program and takes could be more definitively assigned to stocks. Good quality photographs of dorsal fins could be submitted to the Gulf of Mexico Dolphin Identification System (GoMDIS), a collaborative Gulf-wide bottlenose dolphin identification catalog, to determine if bycaught individuals match known animals from BSE stocks. Recent stock assessment surveys have been conducted for a couple of inshore bottlenose dolphin stocks and new abundance estimates are being calculated, but abundance estimates are outdated for most of the remaining inshore stocks. New surveys for inshore stocks would reduce uncertainty in PBR for these stocks. The stocks at highest risk from shrimp fishery bycatch are also those affected by the ongoing northern Gulf of Mexico UME; updated abundance estimates and improved shrimp fishery bycatch rate estimates are particularly important for understanding the status of these stocks.

Limited inferences could be made about gear, vessel, and operating characteristics due to the low numbers of observed catch, but significant differences were found in tow duration and time of day for tows with dolphin bycatch compared to all tows. Catch occurred in tows with significantly longer durations. Whether this is because fishermen tow for longer durations in more productive areas that have higher densities of both shrimp and dolphins, or that longer duration tows result in greater time for an interaction to occur is unknown and deserves further study. The midpoint of tows with dolphin takes occurred later in the day than those without. This may represent a diel behavioral difference or an inability of observers to see a dolphin bycatch event at night. Seasonally, no dolphin bycatch events with mortality or significant injury occurred during summer months (one live release occurred during summer), even given the high effort during this time. Whether this is a real difference due to a change in delphinid or fishermen behavior or an artifact of the overall low observer coverage, the reasons underlying this fact should be further investigated. Finally, the impact of skimmer trawls remains unknown, but their use in inshore waters is increasing and deserves further evaluation. Results of this study indicate shrimp otter trawls are a significant cause of mortality and serious injury for some dolphin stocks. All involved stocks other than FL BSE bottlenose dolphins, Eastern Coastal bottlenose dolphins, and Atlantic spotted dolphins may need to be elevated to strategic status if total anthropogenic mortality exceeds PBR.

ACKNOWLEDGMENTS

We commend the outstanding efforts given by the fishery observers involved in this research effort and the commercial fishing industry for their continued participation. John Cole and James A. Primrose assisted in preparing Gulf of Mexico shrimp trawl otter and skimmer fishery effort data. Laura Engleby, Stacy Horstman, Keith Mullin, Jessica Powell, and Patricia Rosel shared their knowledge of the dolphin stocks and the shrimp fishery, and offered constructive criticism of earlier drafts which greatly improved this work. This work has undergone extensive review, both internal and external to NMFS, and has benefitted from constructive criticism and suggestions offered by Jeff Breiwick, Peter Corkeron, Karin Forney, Marjorie Lyssikatos, and Paul Richards during internal reviews, and by Douglas Nowacek, Andrew Read, and Randy Wells during external review. Documentation of the external review and subsequent revisions can be obtained from the lead author.

LITERATURE CITED

Adams LD, Rosel PE (2006) Population differentiation of the Atlantic spotted dolphin (*Stenella frontalis*) in the western North Atlantic, including the Gulf of Mexico. Marine Biology 148:671-681

Alverson DL, Freeberg MH, Murawski SA, Pope JG (1994) A global assessment of fisheries bycatch and discards. FAO Fishery Technical Papers 339:235

Amante C, Eakins BW (2009) ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis. NOAA Technical Memorandum NESDIS NGDC-24

Andersen MS, Forney KA, Cole TV, Eagle T and others (2008) Differentiating serious and non-serious injury of marine mammals: Report of the serious injury technical workshop. NOAA Technical Memorandum NMFS-OPR 39

Angliss RP, DeMaster DP (1998) Differentiating Serious and Non-Serious Injury of Marine Mammals Taken Incidental to Commercial Fishing Operations. NOAA Tech Memo NMFS-OPR-13

Barlow J, Swartz SLT, Eagle C, Wade PR (1995) US marine mammal stock assessments: guidelines for preparation, background, and a summary of the 1995 assessments. NOAA Technical Memorandum NMFS-OPR-95-6, US Department of Commerce

Baxter KN (1971) Brown shrimp live longer than many biologists believe. Commercial Fishery Review 33:2

Berens P (2009) CircStat: A Matlab Toolbox for Circular Statistics. Journal of Statistical Software 31

Berkeley SA, Pybas DW, Campos WL (1985) Bait shrimp fishery of Biscayne Bay. Florida Sea Grant College Technical Paper 40, Florida Sea Grant College, Gainesville, FL

Bisack K, DiNardo G (1992) Estimating total effort in the Gulf of Maine sink gillnet fishery. In: Report of the Fall Stock Assessment Workshop (13th SAW), Research document SAW 13/3 NEFSC Reference Document 92-02. NOAA/NMFS/Northeast Fisheries Science Center, Woods Hole, MA

Caillouet Jr CW, Hart RA, Nance JM (2011) Simulation of tail weight distributions in biological year 1986–2006 landings of brown shrimp, *Farfantepenaeus aztecus*, from the northern Gulf of Mexico fishery. Marine Fisheries Review 73:27-40

Caldwell DK (1955) Notes on the spotted dolphin, *Stenella plagiodon*, and the first record of the common dolphin, *Delphinus delphis*, in the Gulf of Mexico. Journal of Mammalogy:467-470

Caldwell DK, Caldwell MC (1966) Observations on the distribution, coloration, behavior, and audible sound production of the spotted dolphin, *Stenella plagiodon* (Cope). Los Angeles County Museum of Natural History

Carretta JV, Enriquez L (2012) Marine mammal and seabird bycatch in California gillnet fisheries in 2010. Administrative Report LJ–12–01, available from Southwest Fisheries Science Center, 3333 N. Torrey Pines Court, La Jolla, California 92037

Carretta JV, Price T, Petersen D, Read R (2005) Estimates of marine mammal, sea turtle, and seabird mortality in the California drift gillnet fishery for swordfish and thresher shark, 1996-2002. Marine Fisheries Review 66:21-30

Coale JS, Rulifson RA, Murray JD, Hines R (1994) Comparisons of shrimp catch and bycatch between a skimmer trawl and an otter trawl in the North Carolina inshore shrimp fishery. North American Journal of Fisheries Management 14:751-768

Cochran WG (1977) Sampling Techniques. John Wiley & Sons, New York
Davis RW, Worthy GAJ, Würsig B, Lynn SK, Townsend FI (1996) Diving behavior and at-sea movements of an Atlantic spotted dolphin in the Gulf of Mexico. Marine Mammal Science 12:569-581
Delgado Estrella A (1997) Relación de las toninas, *Tursiops truncatus*, y las toninas moteadas, *Stenella frontalis*, con la actividad camaronera en la Sonda de Campeche, México. Anales del Instituto de Biología serie Zoología 68
Duffield DA, Wells RS (2002) The molecular profile of a resident community of bottlenose dolphins, *Tursiops truncatus*. In: Pfeiffer CJ (ed) Molecular and Cell Biology of Marine Mammals. Krieger Publishing, Melbourne, FL, p 3-11
Epperly S, Avens L, Garrison L, Henwood T and others (2002) Analysis of sea turtle bycatch in the commercial shrimp fisheries of southeast US waters and the Gulf of Mexico. NOAA Technical Memorandum NMFS-SEFSC-490^, NOAA/National Marine Fisheries Service/Southeast Fisheries Science Center, Miami, FL
Epperly SP, Teas WG (2002) Turtle excluder devices-are the escape opening large enough? Fishery Bulletin 100:466-474
Fazioli KL, Hofmann S, Wells RS (2006) Use of Gulf of Mexico coastal waters by distinct assemblages of bottlenose dolphins (*Tursiops truncatus*). Aquatic Mammals 32:212-222
Fertl D, Leatherwood S (1997) Cetacean interactions with trawls: a preliminary review. Journal of Northwest Atlantic Fishery Science 22:219-248
Forney K, Benson S, Cameron G (2001) Central California gillnet effort and bycatch of sensitive species, 1990–1998. Seabird bycatch: trends, roadblocks, and solutions University of Alaska Sea Grant, Fairbanks, Alaska:141-160
Fritts TH, Irvine AB, Jennings RD, Collum LA, Hoffman W, McGehee MA (1983) Turtles, birds, and mammals in the northern Gulf of Mexico and nearby Atlantic waters. An overview based on aerial surveys of OCS areas, with emphasis on oil and gas effects. FWS/OBS-82/65^, Minerals Management Service, Dept of the Interior, Washington, DC 20240
Fulling GL, Mullin KD, Hubard CW (2003) Abundance and distribution of cetaceans in outer continental shelf waters of the U. S. Gulf of Mexico. Fishery Bulletin 101:923-932
Gallaway B (1981) An Ecosystem Analysis of Oil and Gas Development on the Texas-Louisiana Continental Shelf. FWS/OBS-81/27, US Fish and Wildlife Service, Office of Biological Services, Washington, DC
Gallaway BJ, Cole JG, Martin LR, Nance JM, Longnecker M (2003) An evaluation of an electronic logbook as a more accurate method of estimating spatial patterns of trawling effort and bycatch in the Gulf of Mexico shrimp fishery. North American Journal of Fisheries Management 23:787-809
Garrison LP (2003) Estimated bycatch of marine mammals and turtles in the U.S. Atlantic pelagic longline fleet during 2001-2002. NOAA Tech Memo NMFS-SEFSC-515
Garrison LP, Stokes L, Fairfield CP (2009) Estimated bycatch of marine mammals and sea turtles in the U.S. Atlantic pelagic longline fleet during 2008. NOAA Tech Memo NMFS-SEFSC-591
Griffin RB, Griffin NJ (2003) Distribution, habitat partitioning, and abundance of Atlantic spotted dolphins, bottlenose dolphins, and loggerhead sea turtles on the eastern Gulf of Mexico continental shelf. Gulf of Mexico Science 21:23-34

Griffin RB, Griffin NJ (2004) Temporal variation in Atlantic spotted dolphin (*Stenella frontalis*) and bottlenose dolphin (*Tursiops truncatus*) densities on the west Florida continental shelf. Aquatic Mammals 30:380-390

Hart RA, Nance JM, Primrose JA (2012) The US Gulf of Mexico pink shrimp, *Farfantepenaeus duorarum*, fishery: 50 years of commercial catch statistics. Marine Fisheries Review 74:1-6

Hay DE, Harbo R, Boutillier J, Wylie E, Convey L, McCarter PB (1999) Assessment of bycatch in the 1997 and 1998 shrimp trawl fisheries in British Columbia, with emphasis on eulachons. Canadian Stock Assessment Secretariat Research Document 99/179, Biological Services Branch, Fisheries and Oceans Canada, Nanaimo, British Columbia, Canada

Hein S, Meier P (1995) Skimmers: Their development and use in coastal Louisiana. Marine Fisheries Review 57:17-24

Henwood TA, Stunz WE (1987) Analysis of sea turtle captures and mortalities during commercial shrimp trawling. Fishery Bulletin 85:813-817

Hersh SL, Duffield DA (1990) Distinction between northwest Atlantic offshore and coastal bottlenose dolphins based on hemoglobin profile and morphometry. In: Leatherwood S, Reeves RR (eds) The bottlenose dolphin. Academic Press, San Diego, CA, p 129-139

Herzing DL (1997) The life history of free-ranging Atlantic spotted dolphins (*Stenella frontalis*): Age classes, color phases, and female reproduction. Marine Mammal Science 13:576-595

Irvine AB, M.D. Scott, Wells RS, Kaufmann JH (1981) Movements and activities of the Atlantic bottlenose dolphin, *Tursiops truncatus*, near Sarasota, Florida. Fishery Bulletin 79:671-688

Jenkins LD (2012) Reducing sea turtle bycatch in trawl nets: A history of NMFS Turtle Excluder Device (TED) research. Marine Fisheries Review 74:26-44

Kennedy FS, Crane JJ, Schlieder RA, Barber DG (1977) Studies of the rock shrimp, *Sicyonia brevirostris*, a new fishery resource on Florida's Atlantic shelf. Florida Marine Research Publications #27 Florida Department of Natural Resources MRL

Kleiber P (1998) Estimating Annual Takes and Kills of Sea Turtles by the Hawaiian Longline Fishery, 1991-97, from Observer Program and Logbook Data. US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center

Larese JP (2009) Fish and invertebrate bycatch estimates for the Califonia set gillnet fishery targeting halibut and white seabass, 1990-2006.

Larese JP, Coan Jr AL (2008) Fish and invertebrate bycatch estimates for the California drift gillnet fishery targeting swordfish and thresher shark.

Lawson TA (1997) Estimation of bycatch and discards in central and western Pacific tuna fisheries: preliminary results. OFP Internal Report No. 33 (Revised July 1997), Secretariat of the Pacific Community, Noumea, New Caledonia

Lennert-Cody C (2000) Effect of sample size on bycatch estimation. Information Paper Meeting of the IATTC Scientific Working Group, 10 – 14 April 2000, La Jolla, California, United States of America, Inter-American Tropical Tuna Commission, La Jolla, California, United States of America

Levy PS, Lemeshow S (2011) Sampling of populations: methods and applications, Vol 543. Wiley

Linton B (2012) Shrimp fishery bycatch estimates for Gulf of Mexico red snapper, 1972-2011. SEDAR31-DW30, SEDAR, North Charleston, SC
Maiolo JR (2004) Hard Times and a Nickel a Bucket: Struggle and Survival in North Carolina's Shrimp Industry. Chapel Hill Press
Maril RL (1983) Texas shrimpers: community, capitalism, and the sea. Texas A&M University Press, College Station, Texas
Maril RL (1995) Bay shrimpers of Texas: rural fishermen in a global economy. University of Kansas Press, Lawrence
Maze-Foley K, Mullin K (2007) Cetaceans of the oceanic northern Gulf of Mexico: Distributions, group sizes and interspecific associations. Journal of Cetacean Research and Management 8:203
McCracken ML (2000) Estimation of sea turtle take and mortality in the Hawaiian longline fisheries. Administrative Report H-00-06, Honolulu Laboratory, Southwest Fisheries Science Center, National Marine Fisheries Service, Honolulu, Hawaii, United States of America.
Mead JG, Potter CW (1995) Recognizing two populations of the bottlenose dolphin (*Tursiops truncatus*) off the Atlantic coast of North America: Morphological and ecological considerations. IBI Reports 5:31-44
Mills L, Rademacher K (1996) Atlantic spotted dolphins (*Stenella frontalis*) in the Gulf of Mexico. Gulf of Mexico Science 14:114-119
Moore JE, Wallace BP, Lewison RL, Žydelis R, Cox TM, Crowder LB (2009) A review of marine mammal, sea turtle and seabird bycatch in USA fisheries and the role of policy in shaping management. Marine Policy 33:435-451
Mullin K, Hansen L (1999) Marine mammals of the northern Gulf of Mexico. In: Kumpf H, Steidinger K, Sherman K (eds) Gulf of Mexico: A large marine ecosystem. Blackwell Science, Malden, MA., p 269-277
Mullin KD (2007) Abundance of cetaceans in the oceanic Gulf of Mexico based on 2003 - 2004 ship surveys., NMFS, Southeast Fisheries Science Center, P.O. Drawer 1207, Pascagoula, MS 39568
Mullin KD, Fulling GL (2004) Abundance of cetaceans in the oceanic northern Gulf of Mexico, 1996-2001. Marine Mammal Science 20:787-807
Murray KT (2013) Estimated Loggerhead and Unidentified Hard-shelled Turtle Interactions in Mid-Atlantic Gillnet Gear, 2007-2011. NOAA Tech Memo NMFS NE 225:02543-01026
Nance J, Keithly Jr. W, Caillouet Jr. C, Cole J and others (2008) Estimation of Effort, Maximum Sustainable Yield, and Maximum Economic Yield in the Shrimp Fishery of the Gulf of Mexico. NOAA Technical Memorandum NMFS-SEFSC-570
Nance JM (1992) Estimation of effort for the Gulf of Mexico shrimp fishery. US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center, Galveston Laboratory
Nance JM (1993) Effort Trends for the Gulf of Mexico Shrimp Fishery. NOAA Technical Memorandum NMFS-SEFSC-337
Nance JM, Caillouet Jr. CW, Hart RA (2010) Size-composition of annual landings in the white shrimp, *Litopenaeus setiferus,* fishery of the northern Gulf of Mexico 1960-2006: Its trend and relationships with other fishery-dependent variables. Marine Fisheries Review 72:1-13

Nance JN (2004) Estimation of Effort in the Offshore Shrimp Trawl Fishery of the Gulf of Mexico. SEDAR7-DW-24, NOAA Fisheries, SEFSC Galveston Laboratory

National Marine Fisheries Service (1995) Report to Congress: cooperative research program addressing finfish bycatch in the Gulf of Mexico and South Atlantic shrimp fisheries. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Regional Office, St. Petersburg, Florida (available at http://galveston.ssp.nmfs.gov/publications/pdf/620.pdf)

National Marine Fisheries Service (1998) Report to Congress: southeastern United States shrimp trawl bycatch program. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center, Galveston Laboratory, Galveston, Texas (available at http://galveston.ssp.nmfs.gov/publications/pdf/235.pdf)

National Marine Fisheries Service (2005) Revisions to Guidelines for Assessing Marine Mammal Stocks. (available at http://www.nmfs.noaa.gov/pr/pdfs/sars/gamms2005.pdf)

National Marine Fisheries Service (2010) Characterization of the U.S. Gulf of Mexico and southeastern Atlantic otter trawl and bottom reef fish fisheries. Observer Training Manual. NMFS, Southeast Fish. Sci. Cent., Galveston Laboratory, , Galveston, Tex. (avail. at http://www.st.nmfs.noaa.gov/Assets/Observer-Program/pdf/Shrimp_Reef_fish_Manual_9_22_10.pdf

National Marine Fisheries Service (2012) Guidelines for Distinguishing Serious from Non-Serious Injury of Marine Mammals Pursuant to the Marine Mammal Protection Act.

National Marine Fisheries Service (2013a) 2010-2013 Cetacean Unusual Mortality Event in Northern Gulf of Mexico. (available at http://www.nmfs.noaa.gov/pr/health/mmume/cetacean_gulfofmexico2010.htm), (accessed July 2013)

National Marine Fisheries Service (2013b) Sea Turtle Strategy: State Trawl Gear Reports. (available at http://www.nmfs.noaa.gov/pr/species/turtles/trawl.htm), (accessed July 2013)

National Oceanic and Atmospheric Administration (2002) Fisheries of the United States. (available at http://www.st.nmfs.noaa.gov/st1/commercial/index.html), (accessed April 2013)

National Oceanic and Atmospheric Administration (2012) Shrimp Observer Program. (available at http://www.st.nmfs.noaa.gov/observer-home/regions/southeast/shrimp), (accessed April 2013)

National Oceanic and Atmospheric Administration (2013a) Commercial Fishery Landings Database. Annual Commercial Landing Statistics (1997-2011). (available at http://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings/index), (accessed April 2013)

National Oceanic and Atmospheric Administration (2013b) Commercial Fishery Landings Database. Monthly Commercial Landing Statistics (1997-2011). (available at http://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/monthly-landings/index), (accessed April 2013)

Neal RA, Maris RC (1985) Fisheries biology of shrimps and shrimplike animals. In: Jr. AJP (ed) Economic aspects: fisheries and culture, Vol 10: The biology of crustacea. Academic Press, Inc., New York, p 1-110

Nichols S, Shah A, Pellegrin Jr. G, Mullin K (1987) Estimates of annual shrimp fleet bycatch for thirteen finfish species in the offshore waters of the Gulf of Mexico. Report to the Gulf of

Mexico Fisheries Management Council, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula, Mississippi

Northeast Fisheries Science Center (1992) Report of the Thirteenth Northeast Regional Stock Assessment Workshop (13th SAW), Fall 1991. Northeast Fisheries Science Center Reference document 92-06

Northridge S (1996) Estimation of cetacean mortality in the U.S. Atlantic swordfish and tuna driftnet and pair trawl fisheries. NMFS. 40ENNF500160

Orphanides C (2013) Estimates of cetacean and pinniped bycatch during 2010 and 2011 in the New England sink gillnet fishery, Mid-Atlantic gillnet fishery, and two NMFS gillnet experiments. US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center

Orphanides CD (2009) Protected species bycatch estimating approaches: Estimating harbor porpoise bycatch in US northwestern Atlantic gillnet fisheries. J Northw Atl Fish Sci 42:55-76

Patella F (1975) Water surface area within statistical subareas used in reporting Gulf Coast shrimp data. Marine Fisheries Review 37:22-24

Pellegrin Jr. G (1982) Fish discards from the southeastern United States shrimp fishery. In: Fish-bycatch … Bonus from the sea: a report of a technical consultation on shrimp by-catch utilization held in Georgetown, Guyana, 27-30 October 1981. FAO International Development and Research Center, Ottawa, Ontario, p 51-54

Pennington M (1983) Efficient estimators of abundance, for fish and plankton surveys. Biometrics 39:281-286

Perez MA (2006) Analysis of Marine Mammal Bycatch Data From the Trawl, Longline, and Pot Groundfish Fisheries of Alaska, 1998-2004, Defined by Geographic Area, Gear Type, and Catch Target Groundfish Species. NOAA Technical Memorandum NMFS-AFSC-167, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center

Perrin WF, Mitchell ED, Mead JG, Caldwell DK, Caldwell MC, van Bree PJH, Dawbin WH (1987) Revision of the spotted dolphins, *Stenella* spp. Marine Mammal Science 3:99-170

Poffenberger JR (1991) An overview of the data collection procedures for the shrimp fisheries in the Gulf of Mexico. Unpublished report. National Marine Fisheries Service, Miami, FL, p 19

Price B, Gearhart J (2011) Evaluations of turtle excluder device (TED) performance in the US southeast Atlantic and Gulf of Mexico skimmer trawl fisheries. US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center

Pulver JR, Scott-Denton E, Williams JA (2012) Characterization of the U.S. Gulf of Mexico skimmer trawl fishery based on observer coverage. NOAA Technical Memorandum NMFS-SEFSC-636

Read AJ, Drinker P, Northridge S (2006) Bycatch of marine mammals in U.S. and global fisheries. Conservation Biology 20:163-169

Reeves RR, McClellan K, Werner TB (2013) Marine mammal bycatch in gillnet and other entangling net fisheries, 1990 to 2011. Endangered Species Research 20:71-97

Romanov EV (1997) By-catch in the purse seine tuna fisheries in the Western Indian Ocean. Document INF/98/40 Seventh Expert Consultation on Indian Ocean Tunas, 9 – 14

November 1998, Victoria, Mahé, Seychelles, Southern Scientific Research Institute of Marine Fisheries and Oceanography (YugNIRO), Kerch, Crimea, Ukraine
Rosel P, Hansen L, Hohn A (2009) Restricted dispersal in a continuously distributed marine species: common bottlenose dolphins *Tursiops truncatus* in coastal waters of the western North Atlantic. Molecular Ecology 18:5030-5045
Rossman MC (2010) Estimated bycatch of small cetaceans in northeast US bottom trawl fishing gear during 2000-2005. J Northw Atl Fish Sci 42:77-101
Rothschild B, Brunenmeister S (1984) The dynamics and management of shrimp in the northern Gulf of Mexico. In: Gulland JA, Rothschild BJ (eds) Penaeid shrimps—their biology and management. Fishing News Books Ltd., Farnham, Surrey, U.K., p 145-172
Scott-Denton E (2007) U.S. southeastern shrimp and reef fish resources and their management. Ph.D. Dissertation, Texas A&M University
Scott-Denton E, Cryer P, Gocke J, Harrelson M and others (2006) Skimmer trawl fishery catch evaluations in Coastal Louisiana, 2004 and 2005. Marine Fisheries Review 68:30-35
Scott-Denton E, Cryer PF, Duffy MR, Gocke JP and others (2012) Characterization of the U.S. Gulf of Mexico and South Atlantic penaeid and rock shrimp fisheries based on observer data. Marine Fisheries Review 74:1-27
Scott-Denton E, Cryer PF, Gocke JP, Harrelson MR and others (2011) Descriptions of the US Gulf of Mexico reef fish bottom longline and vertical line fisheries based on observer data. Marine Fisheries Review 73:1
Scott GP (1990) Management-oriented research on bottlenose dolphins by the Southeast Fisheries Center. In: Leatherwood S, Reeves RR (eds) The bottlenose dolphin Academic Press, San Diego, CA, p 623-639
Sellas AB, Wells RS, Rosel PE (2005) Mitochondrial and nuclear DNA analyses reveal fine scale geographic structure in bottlenose dolphins (*Tursiops truncatus*) in the Gulf of Mexico. Conservation Genetics 6:715-728
Viricel A (2012) Using Genetics to Assess Population Structure in Three Cetacean Species and to Investigate the Etiology of Cardiomyopathy in *Kogia breviceps*. Ph. D. Dissertation, University of Louisiana at Lafayette
Vollmer N, Rosel P (2012) Developing genomic resources for the common bottlenose dolphin (*Tursiops truncatus*): isolation and characterization of 153 single nucleotide polymorphisms and 53 genotyping assays. Molecular Ecology Resources 12:1124-1132
Vollmer NL (2011) Population Structure of Common Bottlenose Dolphins in Coastal and Offshore Waters of the Gulf of Mexico Revealed by Genetic and Environmental Analysis. PhD Dissertation, University of Louisiana at Lafayette
Vølstad JH, Rickus W, Gaurin S, Easton R (1997) Analytical and statistical review of procedures for collection and analysis of commercial fishery data used for management and assessment of groundfish stocks in the U.S. exclusive economic zone off Alaska. Versar, Inc., Columbia, Maryland, United States of America. (Report prepared for the Alaska Fisheries Science Center, National Marine Fisheries Service, Seattle, Washington, United States of America.
Wade PR, Angliss RP (1997) Guidelines for assessing marine mammal stocks: Report of the GAMMS Workshop, April 3-5, 1996, Seattle, Washington. NOAA Technical Memorandum NMFS-OPR-12, US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources

Warden ML (2010) Bycatch of wintering common and red-throated loons in gillnets off the USA Atlantic coast. Aquatic Biology 10:167-180

Warden ML (2011) Modeling loggerhead sea turtle (*Caretta caretta*) interactions with US Mid-Atlantic bottom trawl gear for fish and scallops, 2005–2008. Biological Conservation 144:2202-2212

Waring GT, Josephson E, Maze-Foley K, Rosel PE (2012) U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments - 2011 NOAA Technical Memorandum NMFS-NE-221 U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, Massachusetts

Waring GT, Josephson E, Maze-Foley K, Rosel PE (2014) U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments - 2013. US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA

Waring GT, Josephson E, Maze-Foley K, Rosel PE (2015 in review) U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments - 2014. NOAA-Technical Memorandum, US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA

Warner DA, McMillen-Jackson AL, Bert TM, Crawford CR (2004) The efficiency of a bycatch reduction device used in skimmer trawls in the Florida shrimp fishery. North American Journal of Fisheries Management 24:853-864

Yeung C (1999) Estimates of marine mammal and marine turtle bycatch by the US Atlantic pelagic longline fleet in 1992-1999. NOAA Tech Memo NMFS-SEFSC 429:23

Zar JH (1999) Biostatistical Analysis. Prentice Hall, Upper Saddle River, NJ

TABLES

Table 1. Summary of 2014 stock assessment information for Gulf of Mexico bottlenose dolphin (Tt) and Atlantic spotted dolphin (Sf) stocks. Estimates in red are NOT VALID as they are older than 8 years. They are included only for a sense of scale when comparing to bycatch mortality estimates. Updated abundance (N_{best} and N_{min}) and Potential Biological Removal (PBR) estimates MUST be completed before bycatch impacts on stocks can be accurately assessed. There are 32 Bay, Sound and Estuary (BSE) stocks managed by NOAA NMFS, however bycatch can only be estimated at the state level resolution (TX, LA, AL/MS, and FL) for these waters. For BSE stocks, N_{best}, N_{min}, and PBR represent the combined total for all BSE stocks found within state waters (Note eastern LA BSE stocks are included in AL/MS waters). The minimum PBR and maximum PBR for all individual BSE stocks in a given state's waters are included in parentheses, and represent the range of scenarios if bycatch is limited to a single stock within that state. Ideally, it would be best to use the PRB of the affected stock if all of a state's BSE bycatch is limited to a single stock; however, geographic resolution of the shrimp fishery effort is limited to the state level and this cannot be determined.

Dolphin Stock	Stocks	N_{best}	CV	N_{min} (min; max)	PBR (min; max)	Last Survey
Tt Shelf	1	51,192	0.10	46,926	469	2011-2012
Tt Western Coastal	1	20,161	0.17	17,491	175	2011-2012
Tt Northern Coastal	1	7,185	0.21	6,044	60	2011-2012
Tt Eastern Coastal	1	12,388	0.13	11,110	111	2011-2012
Tt TX BSE stocks *	6	438	varies	274 (28; 107)	2.8 (0.3; 1.1)	Varies
Tt LA BSE stocks *	5	238	varies	195 (0; 129)	2.0 (0; 1.3)	Varies
Tt AL/MS BSE stocks *	4	1355	varies	813 (0; 551)	8.2 (0; 5.6)	Varies
Tt FL BSE stocks *	16	3683	varies	3015(0; 766)	30 (0; 7.7)	Varies
Sf Northern GoM	1	37,611	0.28	29,844	298	2001-2004

* BSE stocks included in each state are as follows:

1) TX [Laguna Madre; Nueces Bay, Corpus Christi Bay; Copano Bay, Aransas Bay, San Antonio Bay, Redfish Bay, Espiritu Santo Bay; Matagorda Bay, Tres Palacios Bay, Lavaca Bay; West Bay; Galveston Bay, East Bay, Trinity Bay];

2) LA [Sabine Lake; Calcasieu Lake; Vermilion Bay, West Cote Blanche Bay, Atchafalaya Bay; Terrebonne Bay, Timbalier Bay; Barataria Bay (Note Sabine Lake is on the border of LA & TX)];

3) AL/MS [Mississippi River Delta; Mississippi Sound, Lake Borgne, Bay Boudreau; Mobile Bay, Bonsecour Bay; Perdido Bay (Note Perdido Bay is on the border of AL & FL)]; and

4) FL [Pensacola Bay, East Bay; Choctawhatchee Bay; St. Andrew Bay; St. Joseph Bay; St. Vincent Sound, Apalachicola Bay, St. George Sound; Apalachee Bay; Waccasassa Bay, Withlacoochee Bay, Crystal Bay; St. Joseph Sound, Clearwater Harbor; Tampa Bay; Sarasota Bay, Little Sarasota Bay; Lemon Bay, Pine Island Sound, Charlotte Harbor, Gasparilla Sound; Caloosahatchee River; Estero Bay; Chokoloskee Bay, Ten Thousand Islands, Gullivan Bay; Whitewater Bay; Florida Keys (Bahia Honda to Key West)].

Table 2. Annual Gulf of Mexico shrimp trawl fishery effort by strata (state area, depth zone and season), including total effort (left) and effort corrected for otter trawls only (right). Total effort includes skimmer catch in depth zone 0 for State Areas 2 and 3 (bold type). State Areas: 1 = FL , 2 = AL/MS , 3 = LA , 4= TX . Depth Zones: 0 = Inshore, 1 = 0 – 10 fathom (0-18 m); 2 = 10+ fathom (18+ m). Seasons: 1 = Jan – Apr, 2 = May – Aug, 3 = Sept – Dec.

			Total Fishery Effort (Days Fished)				Otter Trawl Fishery Effort (Days Fished)			
Year	State Area	Depth Zone	Season 1	Season 2	Season 3	Annual Total	Season 1	Season 2	Season 3	Annual Total
1997	1	0	539.0	2090.5	532.8	3162.3	539.0	2090.5	532.8	3162.3
1997	1	1	2815.6	2676.6	4104.6	9596.7	2815.6	2676.6	4104.6	9596.7
1997	1	2	11472.4	7339.9	6478.6	25290.9	11472.4	7339.9	6478.6	25290.9
1997	**2**	**0**	**405.6**	**13393.1**	**4800.7**	**18599.5**	**405.6**	**11024.9**	**3943.7**	**15374.2**
1997	2	1	153.0	2483.3	1355.1	3991.4	153.0	2483.3	1355.1	3991.4
1997	2	2	1147.5	3197.8	4321.7	8667.0	1147.5	3197.8	4321.7	8667.0
1997	**3**	**0**	**0.0**	**20264.2**	**14736.0**	**35000.2**	**0.0**	**12626.3**	**8186.7**	**20812.9**
1997	3	1	8014.4	24757.6	26974.1	59746.1	8014.4	24757.6	26974.1	59746.1
1997	3	2	7568.1	19612.1	9348.8	36529.0	7568.1	19612.1	9348.8	36529.0
1997	4	0	600.7	15370.5	11010.0	26981.2	600.7	15370.5	11010.0	26981.2
1997	4	1	2403.3	6007.0	10543.8	18954.1	2403.3	6007.0	10543.8	18954.1
1997	4	2	8515.7	15804.3	20816.8	45136.8	8515.7	15804.3	20816.8	45136.8
1998	1	0	335.8	605.0	376.2	1317.1	335.8	605.0	376.2	1317.1
1998	1	1	3652.9	2897.5	2851.8	9402.2	3652.9	2897.5	2851.8	9402.2
1998	1	2	12548.3	10892.0	9276.4	32716.8	12548.3	10892.0	9276.4	32716.8
1998	**2**	**0**	**369.0**	**8472.8**	**4889.5**	**13731.3**	**369.0**	**6858.9**	**3976.6**	**11204.5**
1998	2	1	67.7	3095.0	2514.9	5677.6	67.7	3095.0	2514.9	5677.6
1998	2	2	1101.0	4169.3	4680.3	9950.6	1101.0	4169.3	4680.3	9950.6
1998	**3**	**0**	**15.3**	**13107.7**	**15925.5**	**29048.5**	**13.9**	**8472.1**	**8596.8**	**17082.8**
1998	3	1	3154.2	39041.0	28237.6	70432.8	3154.2	39041.0	28237.6	70432.8
1998	3	2	8001.6	13281.2	5273.8	26556.5	8001.6	13281.2	5273.8	26556.5
1998	4	0	1356.9	10891.8	7290.3	19539.0	1356.9	10891.8	7290.3	19539.0
1998	4	1	2483.8	4334.7	7896.7	14715.1	2483.8	4334.7	7896.7	14715.1
1998	4	2	10126.2	15559.9	21860.8	47546.9	10126.2	15559.9	21860.8	47546.9
1999	1	0	393.9	887.1	588.7	1869.7	393.9	887.1	588.7	1869.7
1999	1	1	1666.2	1156.4	1819.1	4641.6	1666.2	1156.4	1819.1	4641.6
1999	1	2	9380.0	4425.3	4528.5	18333.9	9380.0	4425.3	4528.5	18333.9
1999	**2**	**0**	**460.7**	**13601.6**	**7796.3**	**21858.6**	**460.7**	**10755.5**	**5798.8**	**17015.0**
1999	2	1	555.2	4243.5	2670.0	7468.7	555.2	4243.5	2670.0	7468.7
1999	2	2	2496.7	3042.1	2418.2	7957.1	2496.7	3042.1	2418.2	7957.1
1999	**3**	**0**	**301.4**	**16075.3**	**17898.6**	**34275.3**	**298.9**	**8897.4**	**9353.3**	**18549.5**
1999	3	1	12684.3	37259.0	27456.0	77399.3	12684.3	37259.0	27456.0	77399.3
1999	3	2	6396.0	11567.0	8455.6	26418.5	6396.0	11567.0	8455.6	26418.5
1999	4	0	1910.8	5865.9	4219.5	11996.3	1910.8	5865.9	4219.5	11996.3
1999	4	1	4335.9	6715.0	3872.6	14923.5	4335.9	6715.0	3872.6	14923.5
1999	4	2	8483.6	14847.0	20001.5	43332.1	8483.6	14847.0	20001.5	43332.1
2000	1	0	1263.0	573.2	274.3	2110.4	1263.0	573.2	274.3	2110.4
2000	1	1	2353.5	1129.3	921.5	4404.2	2353.5	1129.3	921.5	4404.2
2000	1	2	7192.2	2741.3	3436.4	13369.8	7192.2	2741.3	3436.4	13369.8
2000	**2**	**0**	**667.5**	**10530.0**	**6437.3**	**17634.8**	**667.5**	**8267.5**	**4582.1**	**13517.1**
2000	2	1	267.9	3626.2	1382.7	5276.8	267.9	3626.2	1382.7	5276.8
2000	2	2	1338.3	4822.8	3061.6	9222.7	1338.3	4822.8	3061.6	9222.7
2000	**3**	**0**	**301.6**	**20377.5**	**14464.5**	**35143.6**	**228.3**	**7740.8**	**4860.1**	**12829.1**
2000	3	1	9670.4	33301.5	26976.0	69947.9	9670.4	33301.5	26976.0	69947.9
2000	3	2	5124.1	13884.5	9207.7	28216.3	5124.1	13884.5	9207.7	28216.3
2000	4	0	2870.8	6772.2	3498.9	13141.8	2870.8	6772.2	3498.9	13141.8
2000	4	1	2574.4	5661.4	5519.4	13755.2	2574.4	5661.4	5519.4	13755.2
2000	4	2	8086.0	17842.5	21951.4	47879.9	8086.0	17842.5	21951.4	47879.9

Year	State Area	Depth Zone	Total Fishery Effort (Days Fished) Season 1	Season 2	Season 3	Annual Total	Otter Trawl Fishery Effort (Days Fished) Season 1	Season 2	Season 3	Annual Total
2001	1	0	893.1	912.4	419.7	2225.2	893.1	912.4	419.7	2225.2
2001	1	1	1666.4	1162.4	1287.0	4115.7	1666.4	1162.4	1287.0	4115.7
2001	1	2	7669.0	4066.6	4516.3	16251.9	7669.0	4066.6	4516.3	16251.9
2001	**2**	**0**	**896.8**	**13712.2**	**6250.1**	**20859.1**	**896.8**	**9903.9**	**5060.1**	**15860.7**
2001	2	1	190.5	2747.9	1553.8	4492.1	190.5	2747.9	1553.8	4492.1
2001	2	2	1296.9	3839.2	3989.7	9125.8	1296.9	3839.2	3989.7	9125.8
2001	**3**	**0**	**104.9**	**20668.7**	**18201.4**	**38975.1**	**17.5**	**6861.8**	**7701.3**	**14580.6**
2001	3	1	11209.3	28338.6	34150.8	73698.7	11209.3	28338.6	34150.8	73698.7
2001	3	2	6179.8	13463.5	11036.4	30679.7	6179.8	13463.5	11036.4	30679.7
2001	4	0	873.2	10486.2	6826.2	18185.6	873.2	10486.2	6826.2	18185.6
2001	4	1	2497.4	1945.8	3925.6	8368.9	2497.4	1945.8	3925.6	8368.9
2001	4	2	9628.5	19285.9	21997.2	50911.7	9628.5	19285.9	21997.2	50911.7
2002	1	0	913.6	1100.7	433.1	2447.4	913.6	1100.7	433.1	2447.4
2002	1	1	1861.7	1862.4	908.8	4632.8	1861.7	1862.4	908.8	4632.8
2002	1	2	10936.7	5210.3	5163.0	21310.0	10936.7	5210.3	5163.0	21310.0
2002	**2**	**0**	**714.7**	**15727.9**	**11232.8**	**27675.4**	**665.7**	**12549.5**	**7526.2**	**20741.4**
2002	2	1	278.6	2665.7	3149.5	6093.8	278.6	2665.7	3149.5	6093.8
2002	2	2	808.7	4572.9	3499.1	8880.7	808.7	4572.9	3499.1	8880.7
2002	**3**	**0**	**7122.1**	**25719.9**	**20635.2**	**53477.3**	**5895.6**	**10561.2**	**8221.5**	**24678.3**
2002	3	1	6477.7	18270.8	35342.2	60090.7	6477.7	18270.8	35342.2	60090.7
2002	3	2	5753.8	35007.5	10258.6	51019.9	5753.8	35007.5	10258.6	51019.9
2002	4	0	771.5	8401.9	5245.5	14418.9	771.5	8401.9	5245.5	14418.9
2002	4	1	1669.3	3752.6	4112.4	9534.3	1669.3	3752.6	4112.4	9534.3
2002	4	2	7936.2	16053.6	21068.6	45058.5	7936.2	16053.6	21068.6	45058.5
2003	1	0	788.1	832.7	131.6	1752.4	788.1	832.7	131.6	1752.4
2003	1	1	721.4	1238.4	1262.2	3222.0	721.4	1238.4	1262.2	3222.0
2003	1	2	7227.3	7971.3	3723.0	18921.6	7227.3	7971.3	3723.0	18921.6
2003	**2**	**0**	**580.5**	**10917.4**	**7586.3**	**19084.2**	**554.1**	**8841.1**	**5580.5**	**14975.7**
2003	2	1	279.5	3209.3	1293.8	4782.6	279.5	3209.3	1293.8	4782.6
2003	2	2	539.6	3037.5	2664.8	6241.9	539.6	3037.5	2664.8	6241.9
2003	**3**	**0**	**4354.5**	**40341.6**	**11719.8**	**56415.9**	**3680.0**	**18145.9**	**4735.1**	**26561.0**
2003	3	1	3406.6	23007.0	22937.7	49351.2	3406.6	23007.0	22937.7	49351.2
2003	3	2	3260.5	29798.0	8560.0	41618.4	3260.5	29798.0	8560.0	41618.4
2003	4	0	421.8	5329.1	3459.6	9210.4	421.8	5329.1	3459.6	9210.4
2003	4	1	953.8	2961.4	4180.1	8095.3	953.8	2961.4	4180.1	8095.3
2003	4	2	4763.1	13807.1	17332.3	35902.5	4763.1	13807.1	17332.3	35902.5
2004	1	0	243.0	564.6	505.3	1312.8	243.0	564.6	505.3	1312.8
2004	1	1	730.6	285.6	459.1	1475.3	730.6	285.6	459.1	1475.3
2004	1	2	10565.9	5184.7	3811.8	19562.4	10565.9	5184.7	3811.8	19562.4
2004	**2**	**0**	**222.9**	**9396.7**	**4815.2**	**14434.8**	**153.9**	**7225.1**	**3052.5**	**10431.6**
2004	2	1	100.3	2279.1	1661.5	4040.9	100.3	2279.1	1661.5	4040.9
2004	2	2	931.2	2930.6	1532.9	5394.7	931.2	2930.6	1532.9	5394.7
2004	**3**	**0**	**3984.9**	**21501.6**	**20508.0**	**45994.5**	**3297.2**	**9984.5**	**7564.9**	**20846.6**
2004	3	1	3177.3	16334.8	17663.1	37175.2	3177.3	16334.8	17663.1	37175.2
2004	3	2	4153.3	18735.9	9049.8	31938.9	4153.3	18735.9	9049.8	31938.9
2004	4	0	430.2	2792.9	3054.6	6277.7	430.2	2792.9	3054.6	6277.7
2004	4	1	2098.2	3411.2	2257.4	7766.8	2098.2	3411.2	2257.4	7766.8
2004	4	2	3045.9	17480.2	18743.6	39269.7	3045.9	17480.2	18743.6	39269.7
2005	1	0	539.8	275.0	257.7	1072.5	539.8	275.0	257.7	1072.5
2005	1	1	212.5	205.8	444.1	862.4	212.5	205.8	444.1	862.4
2005	1	2	7429.7	4113.3	3524.2	15067.2	7429.7	4113.3	3524.2	15067.2
2005	**2**	**0**	**287.1**	**3690.7**	**2413.7**	**6391.5**	**264.4**	**2888.7**	**1286.9**	**4440.0**
2005	2	1	369.6	1829.3	553.6	2752.4	369.6	1829.3	553.6	2752.4

Year	State Area	Depth Zone	Total Fishery Effort (Days Fished) Season 1	Season 2	Season 3	Annual Total	Otter Trawl Fishery Effort (Days Fished) Season 1	Season 2	Season 3	Annual Total
2005	2	2	883.0	3247.3	1820.1	5950.4	883.0	3247.3	1820.1	5950.4
2005	**3**	**0**	**3044.4**	**19416.7**	**12352.5**	**34813.5**	**2745.7**	**8470.7**	**4453.4**	**15669.7**
2005	3	1	2483.2	11733.8	8032.0	22249.1	2483.2	11733.8	8032.0	22249.1
2005	3	2	3450.5	15429.2	4953.5	23833.1	3450.5	15429.2	4953.5	23833.1
2005	4	0	499.3	2831.1	1571.0	4901.4	499.3	2831.1	1571.0	4901.4
2005	4	1	1169.3	1569.2	1742.6	4481.1	1169.3	1569.2	1742.6	4481.1
2005	4	2	3097.6	11912.3	12634.2	27644.1	3097.6	11912.3	12634.2	27644.1
2006	1	0	464.4	563.1	8.2	1035.7	464.4	563.1	8.2	1035.7
2006	1	1	1001.8	642.1	54.9	1698.8	1001.8	642.1	54.9	1698.8
2006	1	2	3386.7	3060.6	1817.8	8265.0	3386.7	3060.6	1817.8	8265.0
2006	**2**	**0**	**699.6**	**3097.3**	**1664.8**	**5461.7**	**474.2**	**2208.1**	**1095.1**	**3777.3**
2006	2	1	638.8	1521.1	547.3	2707.2	638.8	1521.1	547.3	2707.2
2006	2	2	1137.3	2479.6	1744.2	5361.0	1137.3	2479.6	1744.2	5361.0
2006	**3**	**0**	**4802.2**	**23441.3**	**10470.1**	**38713.5**	**2688.0**	**9473.2**	**4136.7**	**16297.9**
2006	3	1	4443.1	17035.1	10604.2	32082.5	4443.1	17035.1	10604.2	32082.5
2006	3	2	3043.1	10788.8	4407.1	18239.0	3043.1	10788.8	4407.1	18239.0
2006	4	0	240.4	813.6	440.6	1494.6	240.4	813.6	440.6	1494.6
2006	4	1	1608.3	1302.7	921.9	3833.0	1608.3	1302.7	921.9	3833.0
2006	4	2	3608.6	5458.7	11118.6	20186.0	3608.6	5458.7	11118.6	20186.0
2007	1	0	117.6	257.5	35.3	410.4	117.6	257.5	35.3	410.4
2007	1	1	500.7	550.9	138.7	1190.3	500.7	550.9	138.7	1190.3
2007	1	2	1677.9	2370.8	866.3	4914.9	1677.9	2370.8	866.3	4914.9
2007	**2**	**0**	**443.3**	**5636.5**	**3819.7**	**9899.5**	**363.3**	**3964.8**	**2510.8**	**6838.9**
2007	2	1	446.0	2169.8	1540.7	4156.4	446.0	2169.8	1540.7	4156.4
2007	2	2	734.1	2737.0	1847.1	5318.1	734.1	2737.0	1847.1	5318.1
2007	**3**	**0**	**2503.7**	**16125.6**	**12800.8**	**31430.1**	**2011.5**	**7118.0**	**4588.3**	**13717.8**
2007	3	1	3086.3	16319.8	9628.8	29034.9	3086.3	16319.8	9628.8	29034.9
2007	3	2	3326.0	5871.4	5764.7	14962.0	3326.0	5871.4	5764.7	14962.0
2007	4	0	117.2	1415.3	1362.9	2895.4	117.2	1415.3	1362.9	2895.4
2007	4	1	778.8	901.1	3436.9	5116.9	778.8	901.1	3436.9	5116.9
2007	4	2	1613.3	5401.1	9024.8	16039.2	1613.3	5401.1	9024.8	16039.2
2008	1	0	88.7	19.0	0.3	108.0	88.7	19.0	0.3	108.0
2008	1	1	154.1	282.0	203.6	639.8	154.1	282.0	203.6	639.8
2008	1	2	1576.4	1187.0	1259.7	4023.0	1576.4	1187.0	1259.7	4023.0
2008	**2**	**0**	**466.4**	**6573.0**	**5421.8**	**12461.2**	**402.4**	**3754.6**	**2713.6**	**6870.6**
2008	2	1	307.5	3288.0	2185.2	5780.6	307.5	3288.0	2185.2	5780.6
2008	2	2	507.0	1519.3	640.6	2666.9	507.0	1519.3	640.6	2666.9
2008	**3**	**0**	**4074.0**	**13214.7**	**12534.5**	**29823.1**	**3120.6**	**5327.4**	**3974.3**	**12422.4**
2008	3	1	1694.9	10777.6	8448.7	20921.2	1694.9	10777.6	8448.7	20921.2
2008	3	2	2335.3	4007.0	3211.0	9553.4	2335.3	4007.0	3211.0	9553.4
2008	4	0	93.7	1123.9	479.1	1696.7	93.7	1123.9	479.1	1696.7
2008	4	1	1685.4	2975.3	1867.1	6527.8	1685.4	2975.3	1867.1	6527.8
2008	4	2	1107.2	3906.9	7670.6	12684.7	1107.2	3906.9	7670.6	12684.7
2009	1	0	964.6	1669.9	491.3	3125.8	964.6	1669.9	491.3	3125.8
2009	1	1	486.4	373.4	147.5	1007.2	486.4	373.4	147.5	1007.2
2009	1	2	3020.7	1772.0	2571.7	7364.3	3020.7	1772.0	2571.7	7364.3
2009	**2**	**0**	**775.5**	**5055.7**	**6040.8**	**11871.9**	**739.7**	**3534.3**	**4055.1**	**8329.1**
2009	2	1	785.5	2735.0	2695.6	6216.1	785.5	2735.0	2695.6	6216.1
2009	2	2	440.7	1222.9	1276.1	2939.7	440.7	1222.9	1276.1	2939.7
2009	**3**	**0**	**7272.9**	**19748.8**	**12541.4**	**39563.1**	**6115.5**	**12425.3**	**6668.1**	**25208.8**
2009	3	1	3250.6	15553.7	7944.4	26748.7	3250.6	15553.7	7944.4	26748.7
2009	3	2	2839.2	6145.8	2738.4	11723.5	2839.2	6145.8	2738.4	11723.5
2009	4	0	92.3	1107.4	633.4	1833.1	92.3	1107.4	633.4	1833.1

Year	State Area	Depth Zone	Total Fishery Effort (Days Fished) Season 1	Season 2	Season 3	Annual Total	Otter Trawl Fishery Effort (Days Fished) Season 1	Season 2	Season 3	Annual Total
2009	4	1	1959.7	1551.5	2252.2	5763.4	1959.7	1551.5	2252.2	5763.4
2009	4	2	1485.0	4527.3	8732.9	14745.2	1485.0	4527.3	8732.9	14745.2
2010	1	0	959.0	2396.1	403.3	3758.4	959.0	2396.1	403.3	3758.4
2010	1	1	495.3	643.7	124.5	1263.5	495.3	643.7	124.5	1263.5
2010	1	2	2912.0	1841.4	843.4	5596.8	2912.0	1841.4	843.4	5596.8
2010	**2**	**0**	**1814.3**	**1490.0**	**7638.8**	**10943.1**	**1722.4**	**509.3**	**3360.9**	**5592.6**
2010	2	1	518.4	65.6	936.5	1520.6	518.4	65.6	936.5	1520.6
2010	2	2	333.3	25.3	508.1	866.7	333.3	25.3	508.1	866.7
2010	**3**	**0**	**6915.2**	**9756.4**	**13197.2**	**29868.8**	**6397.4**	**3999.7**	**4437.8**	**14834.8**
2010	3	1	2043.6	9489.0	7408.8	18941.4	2043.6	9489.0	7408.8	18941.4
2010	3	2	4124.6	4194.0	4808.9	13127.5	4124.6	4194.0	4808.9	13127.5
2010	4	0	58.7	1937.1	1319.3	3315.0	58.7	1937.1	1319.3	3315.0
2010	4	1	1198.7	2917.9	2322.2	6438.8	1198.7	2917.9	2322.2	6438.8
2010	4	2	2033.1	4118.0	6612.0	12763.1	2033.1	4118.0	6612.0	12763.1
2011	1	0	500.4	2095.7	921.6	3517.7	500.4	2095.7	921.6	3517.7
2011	1	1	173.6	424.6	153.9	752.0	173.6	424.6	153.9	752.0
2011	1	2	1777.2	2086.3	1205.4	5068.9	1777.2	2086.3	1205.4	5068.9
2011	**2**	**0**	**1636.8**	**4543.4**	**5284.6**	**11464.8**	**1348.0**	**2704.8**	**2773.2**	**6826.0**
2011	2	1	460.0	1778.8	521.0	2759.8	460.0	1778.8	521.0	2759.8
2011	2	2	668.3	1548.6	762.7	2979.7	668.3	1548.6	762.7	2979.7
2011	**3**	**0**	**6528.0**	**16483.6**	**15838.8**	**38850.4**	**5146.4**	**8838.3**	**7270.9**	**21255.6**
2011	3	1	3003.2	10139.8	6203.3	19346.3	3003.2	10139.8	6203.3	19346.3
2011	3	2	2463.4	7779.4	4095.5	14338.3	2463.4	7779.4	4095.5	14338.3
2011	4	0	62.8	717.0	415.0	1194.8	62.8	717.0	415.0	1194.8
2011	4	1	613.6	1388.2	2047.3	4049.1	613.6	1388.2	2047.3	4049.1
2011	4	2	3251.1	5065.0	9167.3	17483.3	3251.1	5065.0	9167.3	17483.3

Table 3. Gulf of Mexico shrimp trawl fishery strata (by state areas and depth zones) associations with delphinid stocks. Upper panel refers to common bottlenose dolphin, (*T. truncatus*) stocks while lower panel refers to Atlantic spotted dolphin (*S. frontalis*) stock. Inshore depth zone encompasses waters inshore of the COLREGs demarcation lines, nearshore encompasses waters from the COLREGS lines out to 10 fathoms (18 m), and offshore waters are those greater than 10 fathoms (18 m) depth. All bay, sound, and estuary (BSE) bottlenose dolphin stocks within a state are grouped for this comparison since fishery effort is only available at the state area resolution level. There is a mismatch between the boundary of the FL and MS/AL state areas and the boundary of the Northern Coastal (N Coastal) and Eastern Coastal (E Coastal) bottlenose dolphin stocks, with the N Coastal stock boundary extending into FL waters along the panhandle.

	TX	LA	MS/AL	FL
Inshore	TX BSEs	LA BSEs	MS/AL BSEs	FL BSEs
Nearshore	W Coastal	W Coastal	N Coastal	E Coastal
Offshore	Shelf	Shelf	Shelf	Shelf
Inshore	-	-	-	-
Nearshore	*S. frontalis*	*S. frontalis*	*S. frontalis*	*S. frontalis*
Offshore	*S. frontalis*	*S. frontalis*	*S. frontalis*	*S. frontalis*

Table 4. Marine mammal bycatch incidents as reported by the Gulf of Mexico shrimp trawl Observer Program on the Protected Species Capture Report (Appendix B). All incidents, except one, occurred on ships towing 4 nets. The February 07, 2010 incident occurred on a ship towing only 2 nets.

Date	Time	Longitude	Latitude	Depth (ft)	Species ID	Entanglement Method	Mammal Status	Observer Program
01/31/1993	22:15	-82.1017	24.8381	60	Marine Mammal	Lazy Line	Not Given [x]	NMFS
12/07/2001	0:30	-88.1372	30.1356	58	Marine Mammal	TED Net	Decomposed	NMFS
03/26/2002	19:12	-82.3950	25.9656	85.6	Marine Mammal	TED Net	Unknown	NMFS
03/05/2003	11:50	-88.1431	30.2378	23	Bottlenose Dolphin	Lazy Line	Fresh Dead	NMFS
09/04/2004	19:54	-93.9992	28.3461	172	Marine Mammal	Lazy Line	Not Given	NMFS
03/09/2006	18:20	-91.7431	28.1339	286	Marine Mammal	TED Net	Decomposed	NMFS
03/27/2007	7:10	-82.4486	26.7056	57	Marine Mammal	TED Net	Not Given	NMFS
12/28/2007	19:46	-91.5792	29.1717	23	Bottlenose Dolphin	Lazy Line	Fresh Dead	NMFS
02/03/2008	0:56	-96.5528	26.2244	180	Dolphin Carcass	Tickler Chain	Decomposed	NMFS
12/02/2008	7:35	-97.1256	26.8603	90	Bottlenose Dolphin	Lazy Line	Fresh Dead	NMFS
05/13/2009	15:56	-97.1939	27.4258	60	Dolphin	Lazy Line	Alive [o]	NMFS
02/07/2010	19:02	-90.1167	29.1228	25.4	Bottlenose Dolphin	TED Net	Fresh Dead	NMFS
11/22/2011	7:35	-96.8731	26.4844	n/a*	Bottlenose Dolphin	Lazy Line	Fresh Dead	NMFS
02/11/2012	7:53	-93.2253	28.1922	215.4	*Tursiops truncatus*	Lazy Line	Alive [x]	non-NMFS

* Based on trip and tow information from other observer forms and Lat/Long, this entanglement occurred in > 60 ft (>10 fathom) waters.

[x] These takes were out of the time-range of this study and were not included in bycatch mortality estimation

[o] This animal was released alive with no apparent injury, and therefore was not included in bycatch mortality estimation. Comments indicated: “The dolphin was tangled in the lazy line; the line was cut. The dolphin appeared in good condition, alive, and with no noticeable injuries.”

Table 5. Unweighted five-year mean of 2007-2011 annual stock bycatch mortality estimates by stratification method and species classification scenario for unidentified dolphins. Coefficients of variation (CV) of the standard error were estimated using standard bootstrap methods, and 95% confidence intervals (CI) were estimated using bias corrected and accelerated bootstrap methods. Annual bycatch mortality estimates for 1997-2011 are included in Appendix E. Species codes: Ud are unidentified dolphins, Tt are bottlenose dolphins (*T. truncatus*), and Sf are Atlantic spotted dolphins (*S. frontalis*). Stratification methods (2-areas, and 4-areas refer to stratification of bycatch rate estimation). The latest available minimum abundance (N_{MIN}) and Potential Biological Removal (PBR) are presented for comparison; estimates older than 8 years are no longer valid and highlighted in red.

	all Ud = Tt			all Ud = Sf			Stock Assessments	
	5-year Mean	CV	95% CI	5-year Mean	CV	95% CI	Last N_{MIN}	Last PBR
2-Area								
Tt Shelf	48	0.41	19 - 99	19	0.68	0.0 - 65	46,926	469
Tt Western Coastal	74	0.52	20 - 202	56	0.57	16 - 157	17,491	175
Tt Northern Coastal	11	0.52	2.7 - 28	7.7	0.57	2.0 - 22	6,044	60
Tt Eastern Coastal	2.3	1.02	0.0 - 13	0	-	-	11,110	111
Tt TX BSE	3.8	0.60	0.9 - 13	2.3	0.70	0.4 - 9.3	274 (28; 107)	2.8 (0.3; 1.1)
Tt LA BSE	64	0.54	19 - 176	54	0.60	10 - 168	195 (0; 129)	2.0 (0; 1.3)
Tt AL/MS BSE	20	0.52	5 - 53	14	0.58	3.7 - 41	813 (0; 551)	8.2 (0; 5.6)
Tt FL BSE	3.4	1.02	0.0 - 19	0	-	-	3015(0; 766)	30 (0; 7.7)
Sf Northern GoM	0	-	-	52	0.52	20 - 163	29,844	298
4-Area								
Tt Shelf	56	0.42	23 - 133	29	0.67	0.0 - 92	46,926	469
Tt Western Coastal	68	0.85	0.0 - 275	68	0.85	0.0 - 275	17,491	175
Tt Northern Coastal	21	0.66	0.0 - 74	10	0.84	0.0 - 33	6,044	60
Tt Eastern Coastal	2.3	0.99	0.0 - 14	0	-	-	11,110	111
Tt TX BSE	0	-	-	0	-	-	274 (28; 107)	2.8 (0.3; 1.1)
Tt LA BSE	88	1.01	0.0 - 457	88	1.01	0.0 - 457	195 (0; 129)	2.0 (0; 1.3)
Tt AL/MS BSE	41	0.67	0.0 - 144	18	0.84	0.0 - 61	813 (0; 551)	8.2 (0; 5.6)
Tt FL BSE	3.4	0.99	0.0 - 21	0	-	-	3015(0; 766)	30 (0; 7.7)
Sf Northern GoM	0	-	-	42	0.45	15 - 98	29,844	298

FIGURES

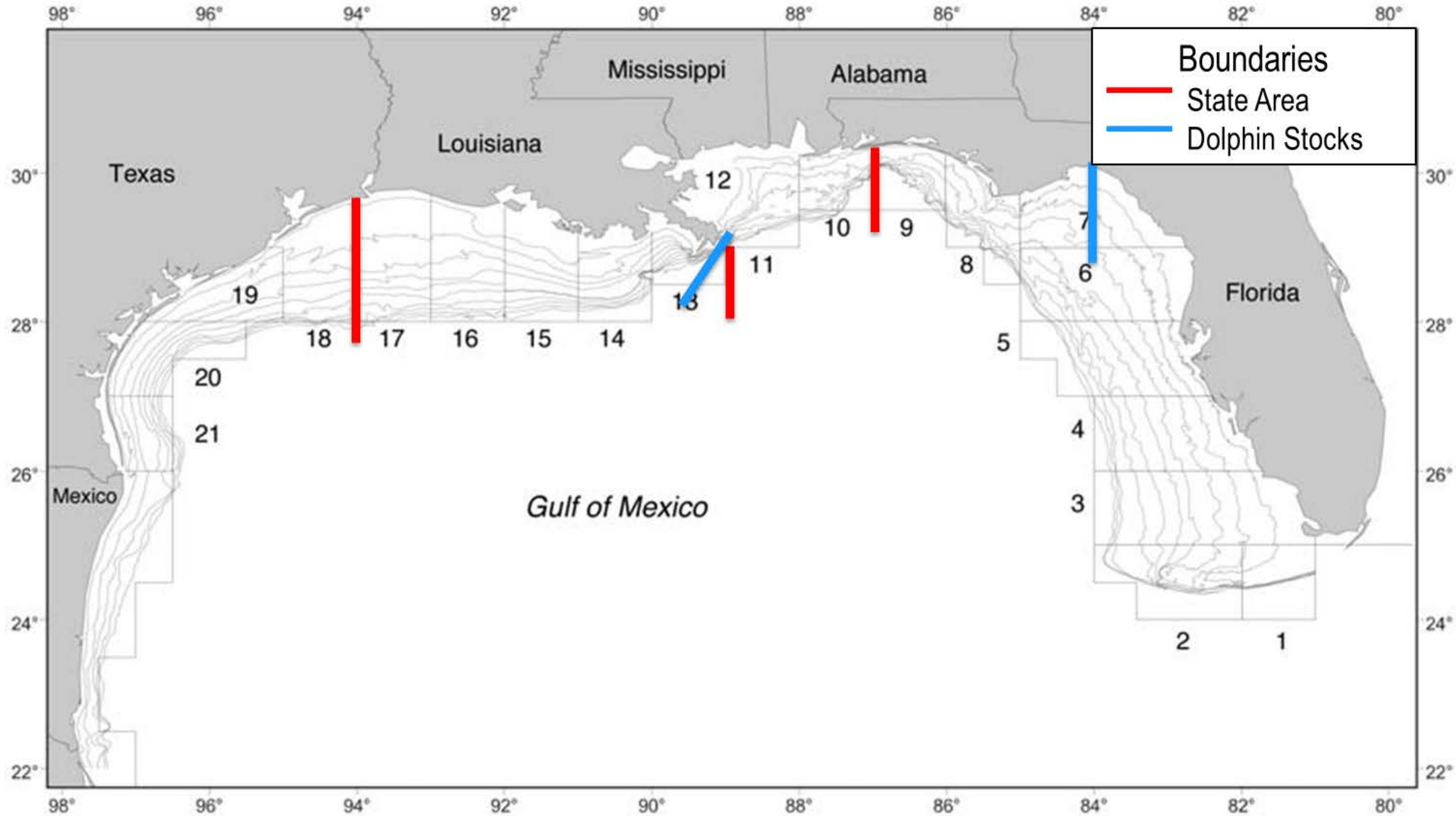


Figure 1. Gulf of Mexico shrimp trawl fishery statistical zones, state area boundaries and coastal bottlenose dolphin stock boundaries. Statistical zones described by Patella (1975) include 21 statistical areas and 9 depth zones based on isobaths in 10 fathom intervals. Statistical areas are grouped into coarser resolution state areas, indicated by the red lines. Coastal bottlenose dolphin stock boundaries are indicated by blue lines.

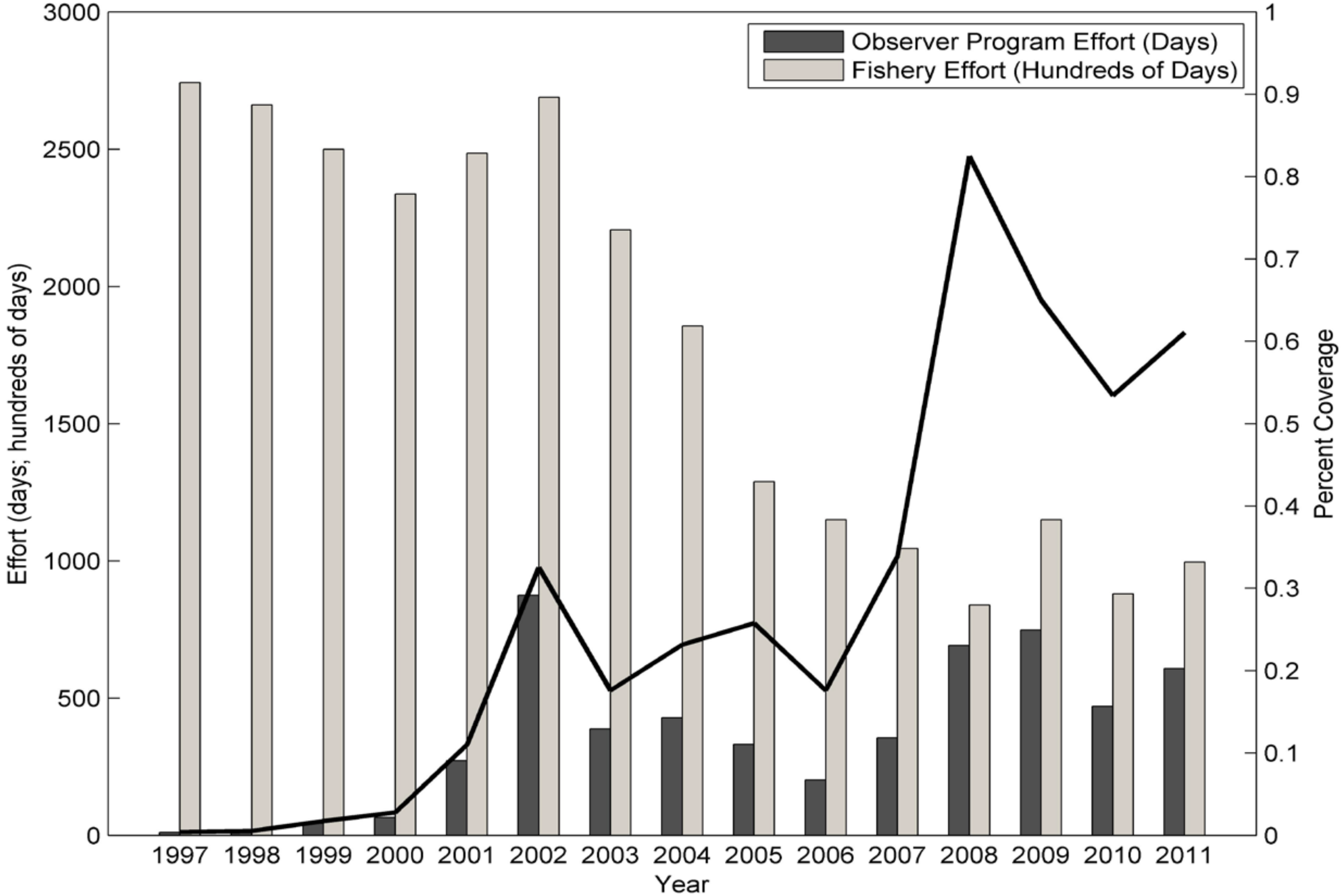


Figure 2. Changes in annual Gulf of Mexico shrimp otter trawl fishery effort ( ), Observer Program effort ( ), and percent coverage (—) between 1997 – 2007. Fishery effort and Observer Program effort are on different scales (hundreds of days and days, respectively).

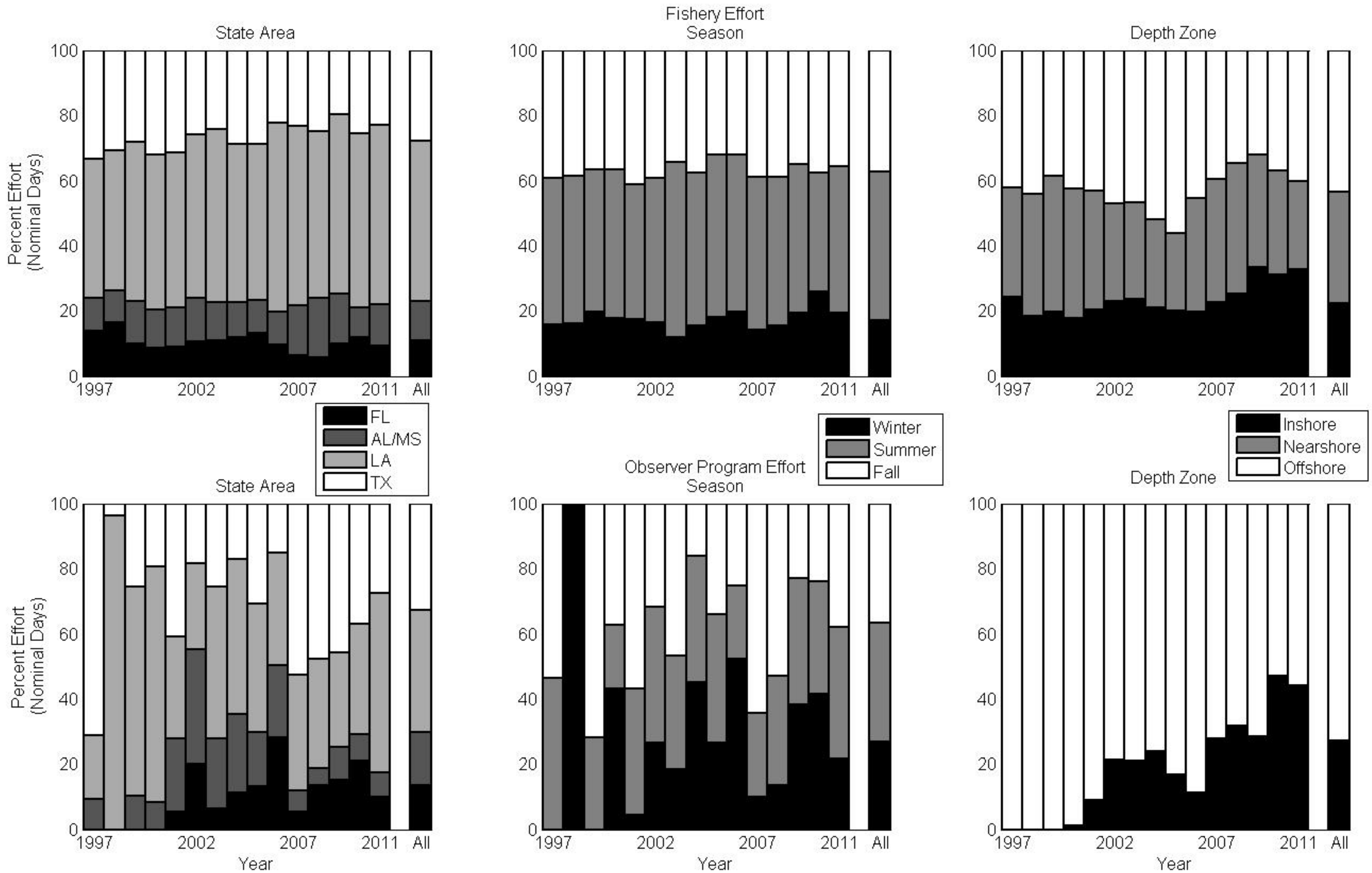


Figure 3. Comparison of annual Gulf of Mexico shrimp otter trawl fishery effort in nominal days actively fished (top panels) and Observer Program effort in nominal days actively fished (lower panels) by state area, season, and depth zone for 1997-2011. Percentage of effort for all years combined is shown to the right of each plot.

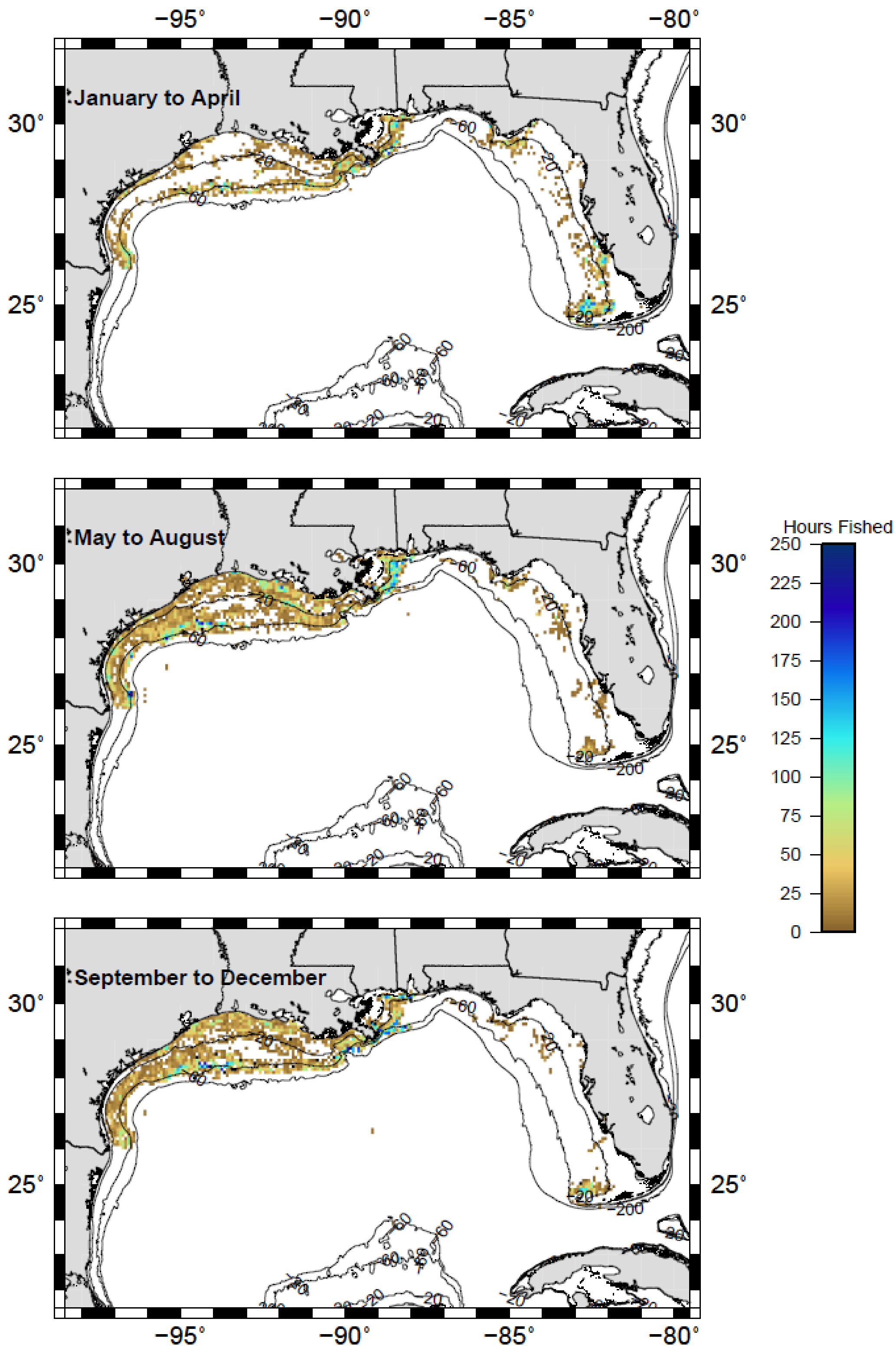


Figure 4. Distribution of fishing effort (hours actively fished) by season for the NMFS Gulf of Mexico shrimp otter trawl fishery Observer Program. Shrimp effort is gridded in 5 arc minute intervals.

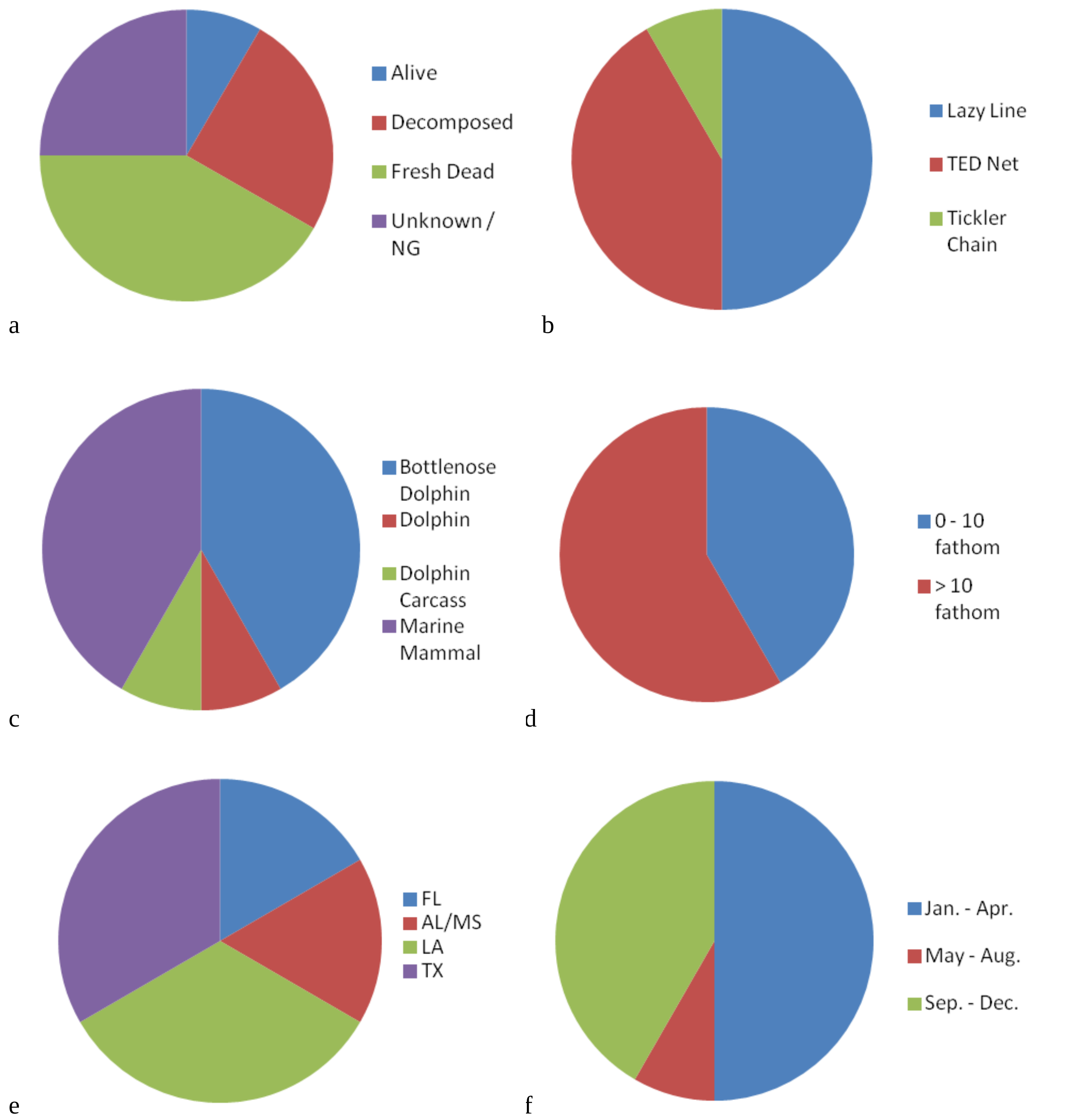


Figure 5. Distribution of fourteen Gulf of Mexico shrimp otter trawl fishery Observer Program marine mammal entanglements by a) injury status, b) gear location, c) species categorization, d) depth range, e) state area, and f) season. Entanglements by fishery strata (depth range, state area, and season) represent observed takes and are not normalized by observed effort, which varies among strata (Figure 4).

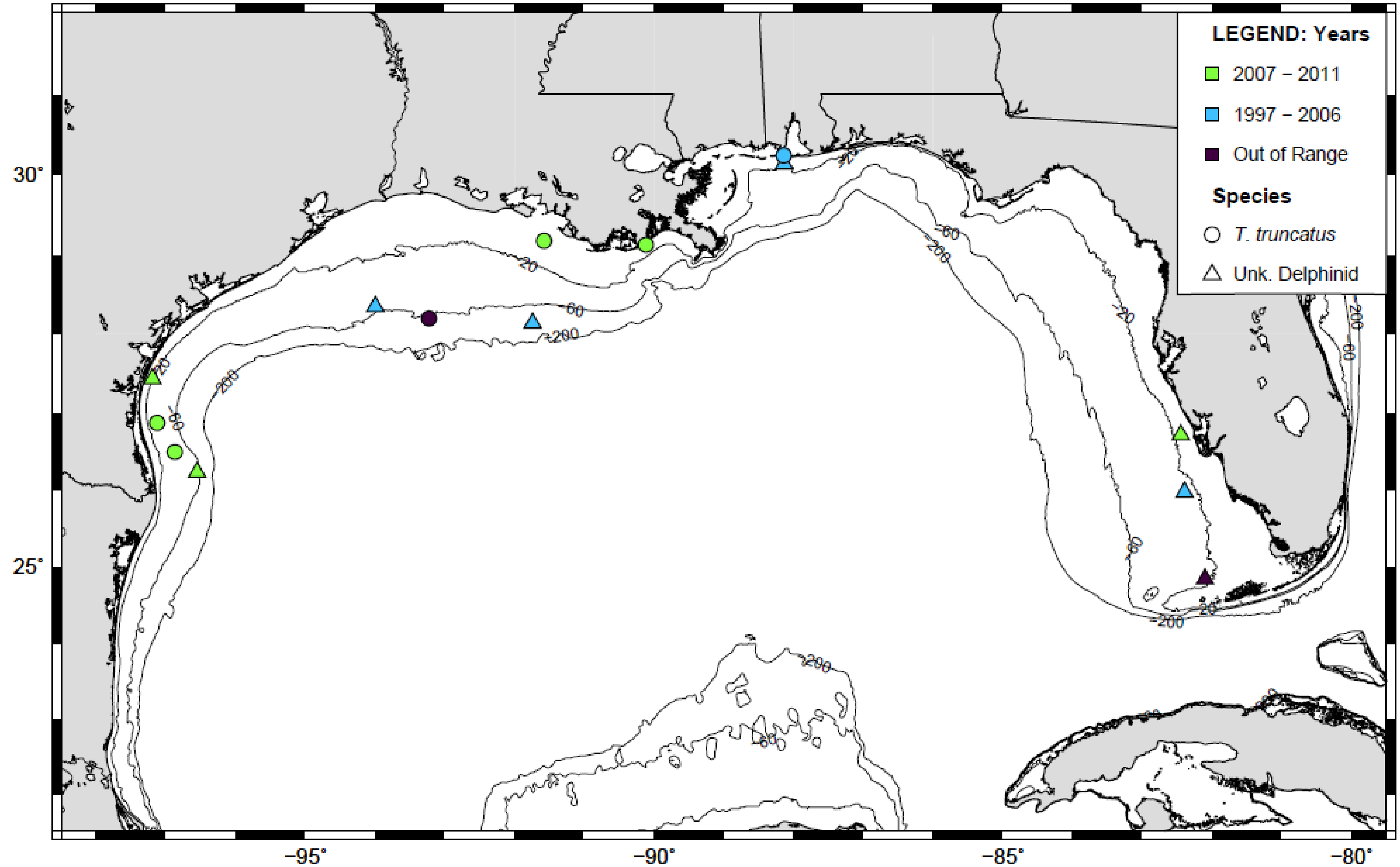


Figure 6. Gulf of Mexico shrimp otter trawl fishery Observer Program marine mammal entanglement locations. Entanglements occurring betwee 1997-2011 are included in bycatch analyses. Entanglements occurring in 1993 and 2012 are outside the range of this study and are not included in bycatch analyses. Data from 1997-2006 were collected when the Observer Program was voluntary, while data from 2007-2011 were collected when the Observer Program was mandatory. Bycaught dolphins were identified as bottlenose dolphin (*T. truncatus*) or remained unidentified and may be bottlenose dolphins or spotted dolphins (*S. frontalis*). Bathymetry is indicated by 20, 60, and 200m isobaths.

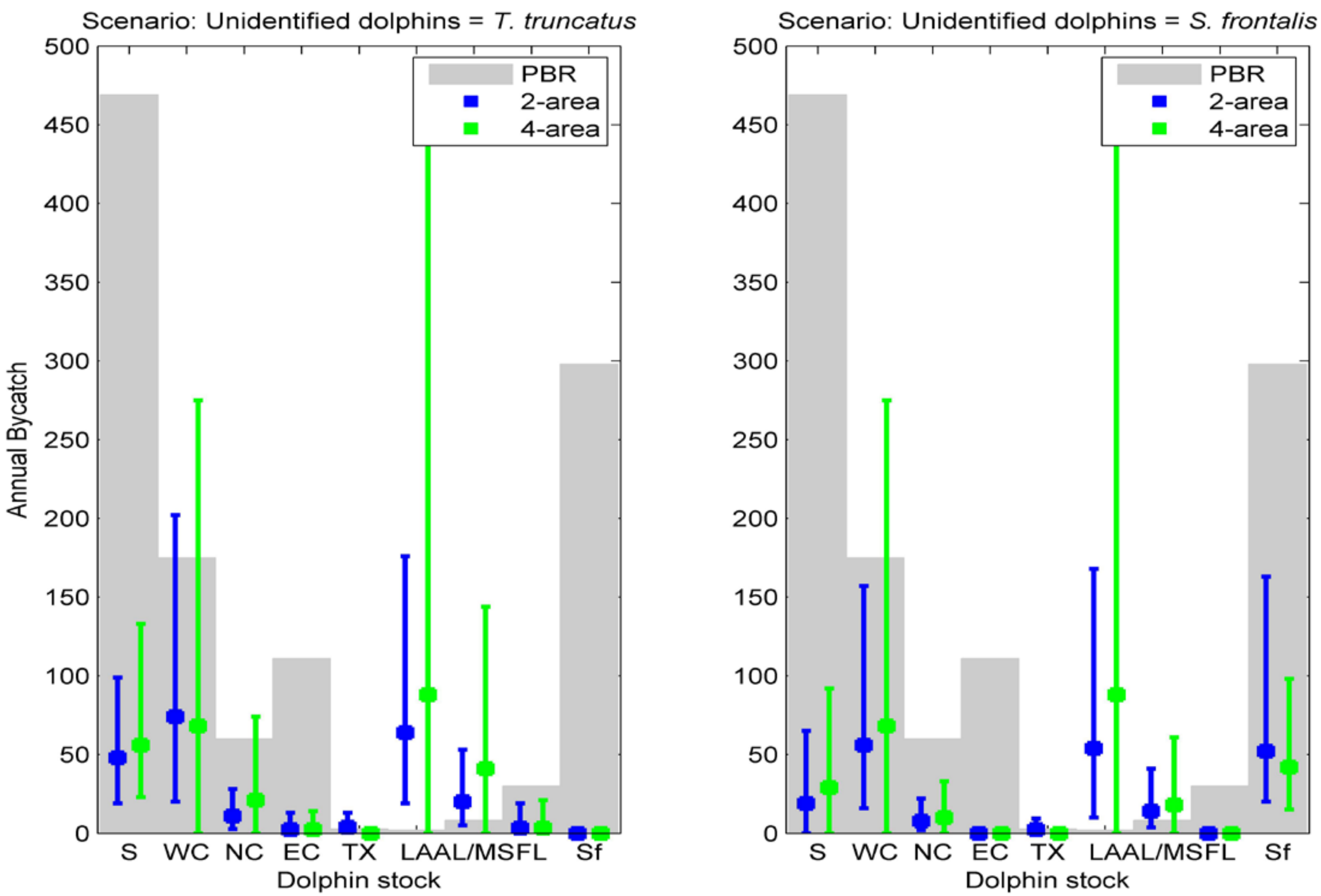


Figure 7. Comparison of estimated bycatch mortality (with 95% CIs) for each stock by stratification method (2-area and 4-area) and under two species identification scenarios. Estimates are presented for 8 stock groups of bottlenose dolphins (Shelf (S), Western Coastal (WC), Northern Coastal (NC), Eastern Coastal (EC), TX BSE (TX), LA BSE (LA), AL/MS BSE (AL/MS), and FL BSE (FL),) and for one stock of Atlantic spotted dolphins (Sf). The two species identification scenarios represent best and worst case scenarios for each species, in which all unidentified takes are assigned to either species. Best available data on Potential Biological Removal (PBR) is shown for reference, but estimates for all bottlenose dolphin Bay, Sound and Estuary (BSE) stocks and the Atlantic spotted dolphin stock are uncertain due to the age (>8 years) of the last abundance estimates. PBR values for BSE stocks represent the aggregate PBR for all stocks within each state area.

APPENDICES

APPENDIX A. Trawl gear configuration reproduced from Scott-Denton et al. (2012)

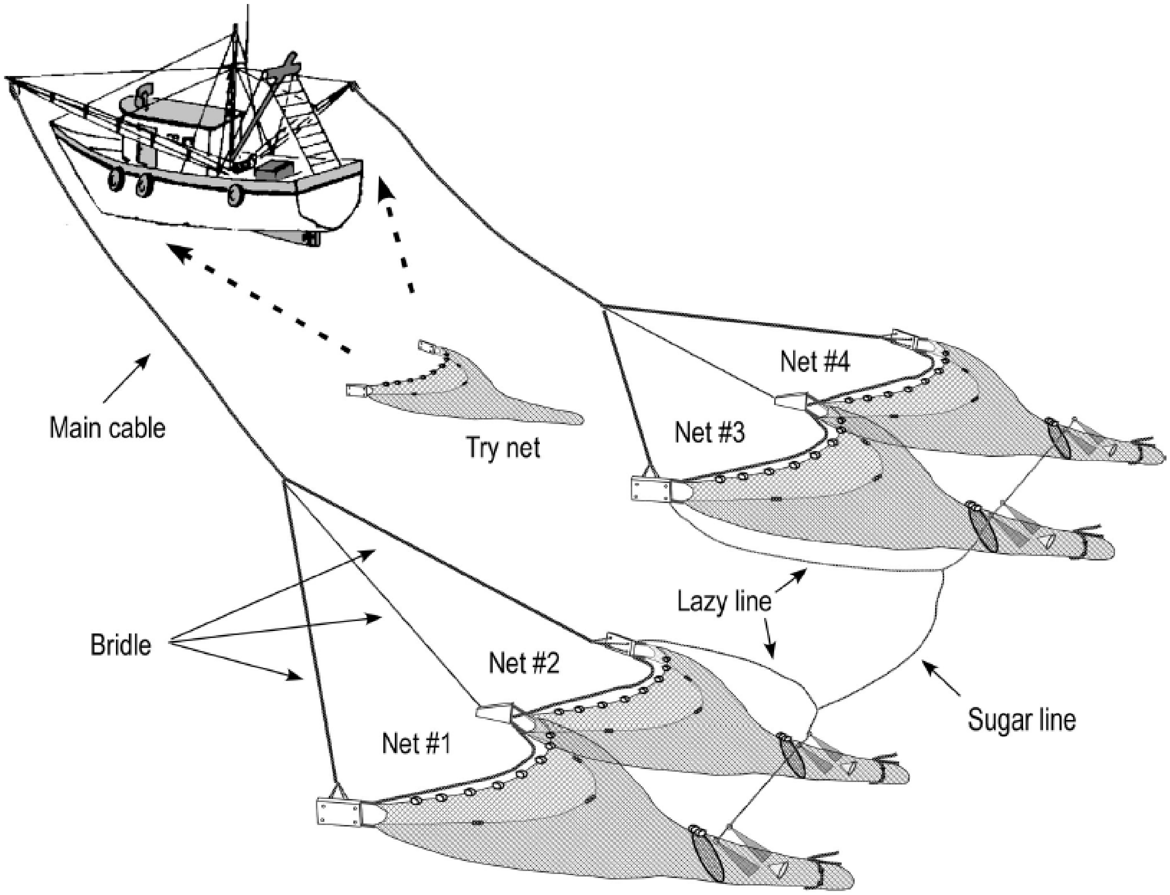


Figure 2.—Typical gear configuration for U.S. southeastern shrimp vessels equipped with four nets.

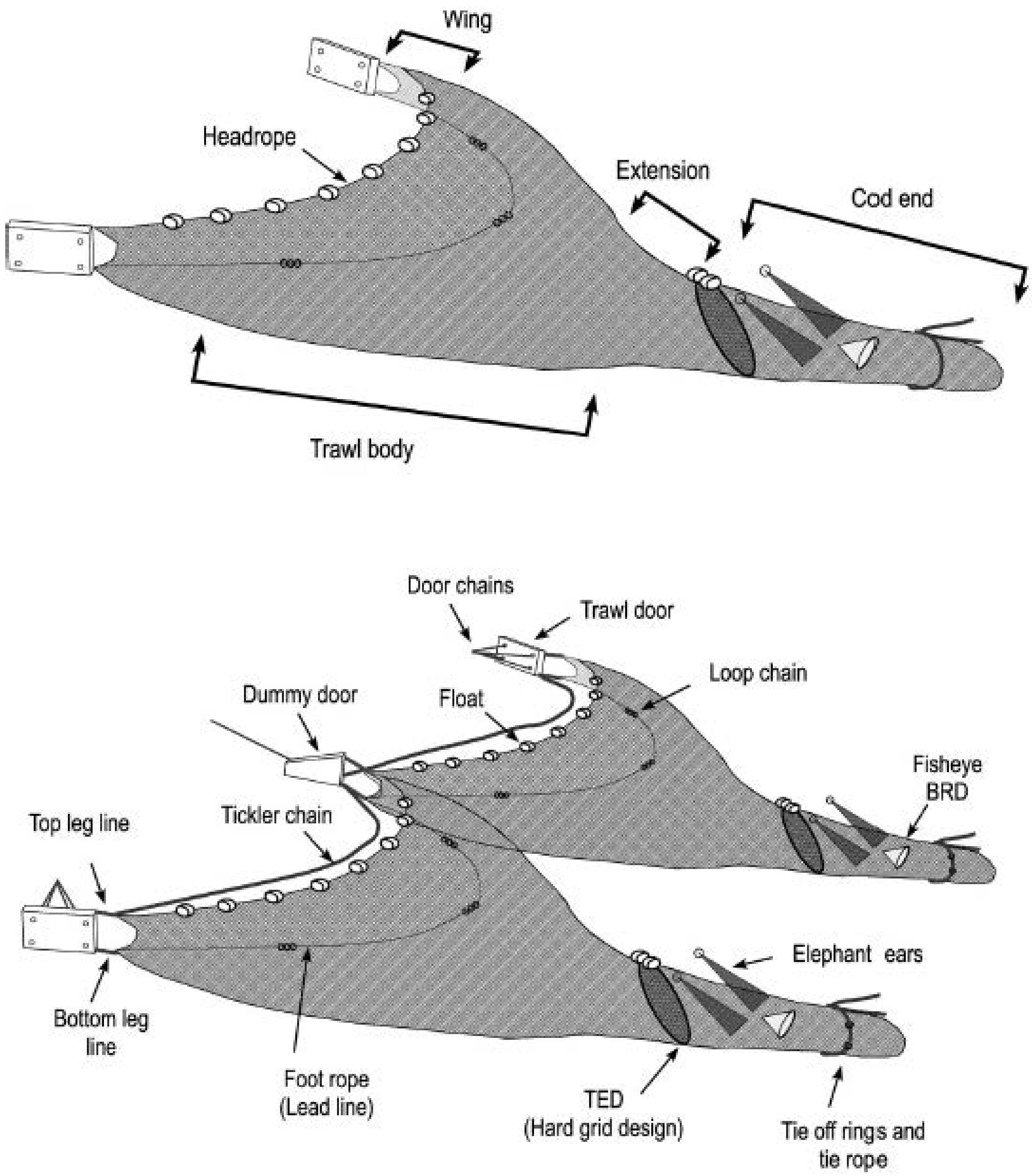


Figure 3.—Typical gear components for U.S. southeastern shrimp vessels.

APPENDIX B. Observer Program bycatch form.

SAWFISH, STURGEON, MARINE MAMMALS, BIRDS

PROTECTED RESOURCES CAPTURE REPORT

REPORT WITH IN 24 HOURS OF CAPTURE 1_10

Trip Number ☐☐☐☐☐☐ MO DY YR ____/____/____ Set/Tow ☐☐☐ ☐ Station ☐ Non-Station ☐ Captured ☐ Sighted Specimen # By Trip ☐☐☐

Check type of specimen captured and reference species (if known) in space provided:

☐ Sawfish ________ ☐ Marine Mammal ________
☐ Sturgeon ________ ☐ Birds ________

Vessel ☐☐☐ Observer ☐☐☐ State ☐☐ Time (24 hr) ☐☐:☐☐ Water Depth (ft.) ☐☐☐.☐ Photos Y/N ☐ Number ☐☐

LATITUDE ☐☐ deg ☐☐ min ☐☐ sec LONGITUDE ☐☐ deg ☐☐ min ☐☐ sec

Gear Type: ☐ Longline ☐ Gill Net ☐ Trawl ☐ Bandit Reel ☐ Handline ☐ Jug ☐ Fish Trap ☐ Spear Fishing

Gear Depth: ☐ Surface ☐ Midwater ☐ Bottom ☐ Other ________

Net Position ☐ Net Type Animal Captured In: ☐ Try Net ☐ Standard Net Net Modifications: ☐ TED ☐ TED/BRD ☐ BRD ☐ None ☐ Unknown

IF GEAR IS A FORM OF HOOK AND LINE, COMPLETE THIS SECTION, AS APPLICABLE:

Hook Type: ☐ "J" ☐ Circle ☐ other (describe)________ SIZE ☐☐ /0

Manufacturer/Style No. ________ DEGREE OFFSET ☐☐°

Bait: ☐ Squid ☐ Mackerel ☐ Sardine ☐ Unknown ☐ Other (describe) ________

Was hook removed from this animal? Y / N / Unknown / Not Applicable

Was animal entangled in gear? At capture? Y / N / Unknown At Release? Y / N / Unknown

How much gear (linear feet) was left on the animal when released? ☐☐☐.☐ ft. (estimated/measured)

TARGET SPECIES: List all targeted species for this set using genus species format.

________ ________ ________ ________

DIMENSIONS (cm):

Estimated total length: ☐☐.☐ ft. Estimated length of saw: ☐☐.☐ ft.

Total Length: ☐☐☐.☐ cm (if boated)

TAG ID NUMBERS:

________ ________ ________ ________

RELEASE INFORMATION: TIME (24hr) ☐☐:☐☐ DATE ____/____/____ MO DY YR

LATITUDE ☐☐ deg ☐☐ min ☐☐ sec LONGITUDE ☐☐ deg ☐☐ min ☐☐ sec

FINAL DISPOSITION: ☐ Discarded Dead/Unresponsive Carcass ☐ Released Alive ☐ Unknown (explain)

ADDITIONAL COMMENTS: (list all biological samples collected):

APPENDIX C. Northern Gulf of Mexico bottlenose dolphin Bay, Sound, and Estuary (BSE) stocks abundance table and map reproduced from (Waring et al. 2014), Waring et al. (2015 in review).

Table 1. Most recent common bottlenose dolphin abundance (N_{BEST}), coefficient of variation (CV) and minimum population estimate (N_{MIN}) in northern Gulf of Mexico bays, sounds and estuaries. Because they are based on data collected more than 8 years ago, most estimates are considered unknown or undetermined for management purposes. Blocks refer to aerial survey blocks illustrated in Figure 1. PBR – Potential Biological Removal; UNK – unknown; UND – undetermined.

Blocks	Gulf of Mexico Estuary	N_{BEST}	CV	N_{MIN}	PBR	Year	Reference
B51	Laguna Madre	80	1.57	UNK	UND	1992	A
B52	Nueces Bay, Corpus Christi Bay	58	0.61	UNK	UND	1992	A
B50	Copano Bay, Aransas Bay, San Antonio Bay, Redfish Bay, Espiritu Santo Bay	55	0.82	UNK	UND	1992	A
B54	Matagorda Bay, Tres Palacios Bay, Lavaca Bay	61	0.45	UNK	UND	1992	A
B55	West Bay	32	0.15	UNK	UND	2000	E
B56	Galveston Bay, East Bay, Trinity Bay	152	0.43	UNK	UND	1992	A
B57	Sabine Lake	0[a]	-		UND	1992	A
B58	Calcasieu Lake	0[a]	-		UND	1992	A
B59	Vermilion Bay, West Cote Blanche Bay, Atchafalaya Bay	0[a]	-		UND	1992	A
B60	Terrebonne Bay, Timbalier Bay	100	0.53	UNK	UND	1993	A
B61	Barataria Bay	138	0.08	UNK	UND	2001	D
B30	Mississippi River Delta	332	0.93	170	1.7	2011-12	J
B02-05, 29, 31	Mississippi Sound, Lake Borgne, Bay Boudreau	901	0.63	551	5.6	2012	J
B06	Mobile Bay, Bonsecour Bay	122	0.34	UNK	UND	1993	A
B07	Perdido Bay	0[a]	-		UND	1993	A
B08	Pensacola Bay, East Bay	33	0.80	UNK	UND	1993	A
B09	Choctawhatchee Bay	179	0.04	173	1.7	2007	H
B10	St. Andrew Bay	124	0.57	UNK	UND	1993	A
B11	St. Joseph Bay	152	0.08	142	1.4	2007	F
B12-13	St. Vincent Sound, Apalachicola Bay, St. George Sound	439	0.14	390	3.9	2007-08	G
B14-15	Apalachee Bay	491	0.39	UNK	UND	1993	A
B16	Waccasassa Bay, Withlacoochee Bay, Crystal Bay	100	0.85	UNK	UND	1994	A
B17	St. Joseph Sound, Clearwater Harbor	37	1.06	UNK	UND	1994	A
B32-34	Tampa Bay	559	0.24	UNK	UND	1994	A
B20, 35	Sarasota Bay, Little Sarasota Bay	160	na[c]	160	1.6	2007	B
B21-23	Pine Island Sound, Charlotte Harbor, Gasparilla Sound, Lemon Bay	826	0.09	UNK	UND	2006	I
B36	Caloosahatchee River	0[a,b]	-		UND	1985	C
B24	Estero Bay	104	0.67	UNK	UND	1994	A
B25	Chokoloskee Bay, Ten Thousand Islands, Gullivan Bay	208	0.46	UNK	UND	1994	A
B27	Whitewater Bay	242	0.37	UNK	UND	1994	A
B28	Florida Keys (Bahia Honda to Key West)	29	1.00	UNK	UND	1994	A

References: A – Blaylock and Hoggard 1994; B – Wells 2009; C – Scott *et al.* 1989; D – Miller 2003; E – Irwin and Würsig 2004; F – Balmer *et al.* 2008; G – Tyson *et al.* 2011; H – Conn *et al.* 2011; I - Bassos-Hull *et al.* 2013; J - NMFS unpublished data

Notes:

[a] During earlier surveys (Scott *et al.* 1989), the range of seasonal abundances was as follows: B57, 0-2 (CV=0.38); B58, 0-6 (0.34); B59, 0-0; B30, 0-182 (0.14); B07, 0-0; B21, 0-15 (0.43); and B36, 0-0.

[b] Block not surveyed during surveys reported in Blaylock and Hoggard (1994).

[c] No CV because N_{BEST} was a direct count of known individuals.

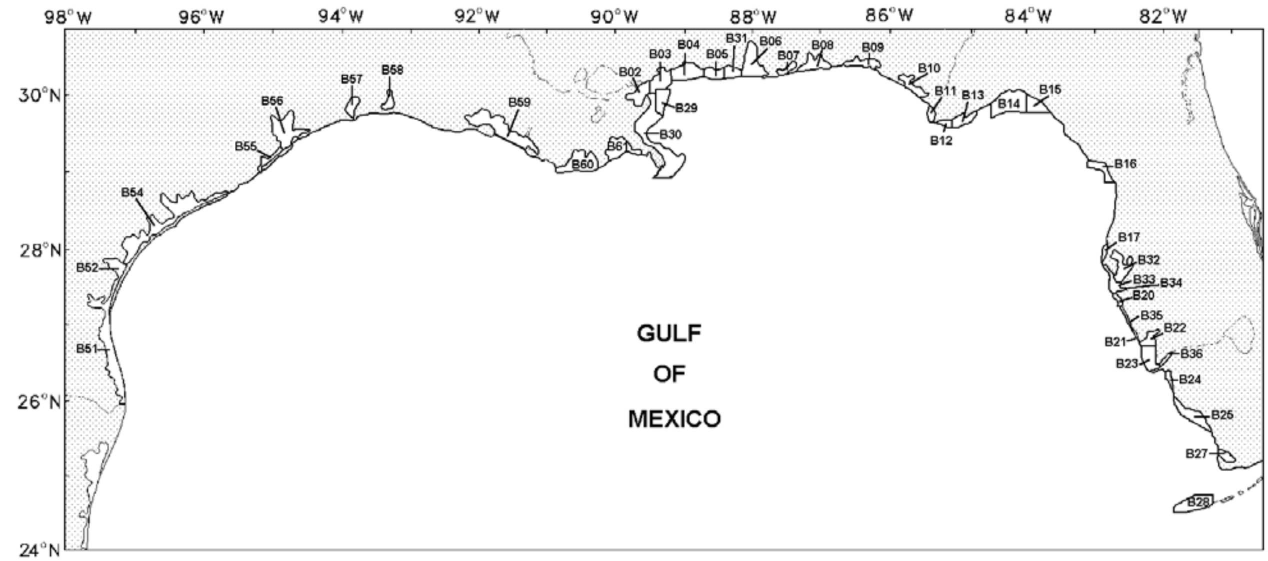
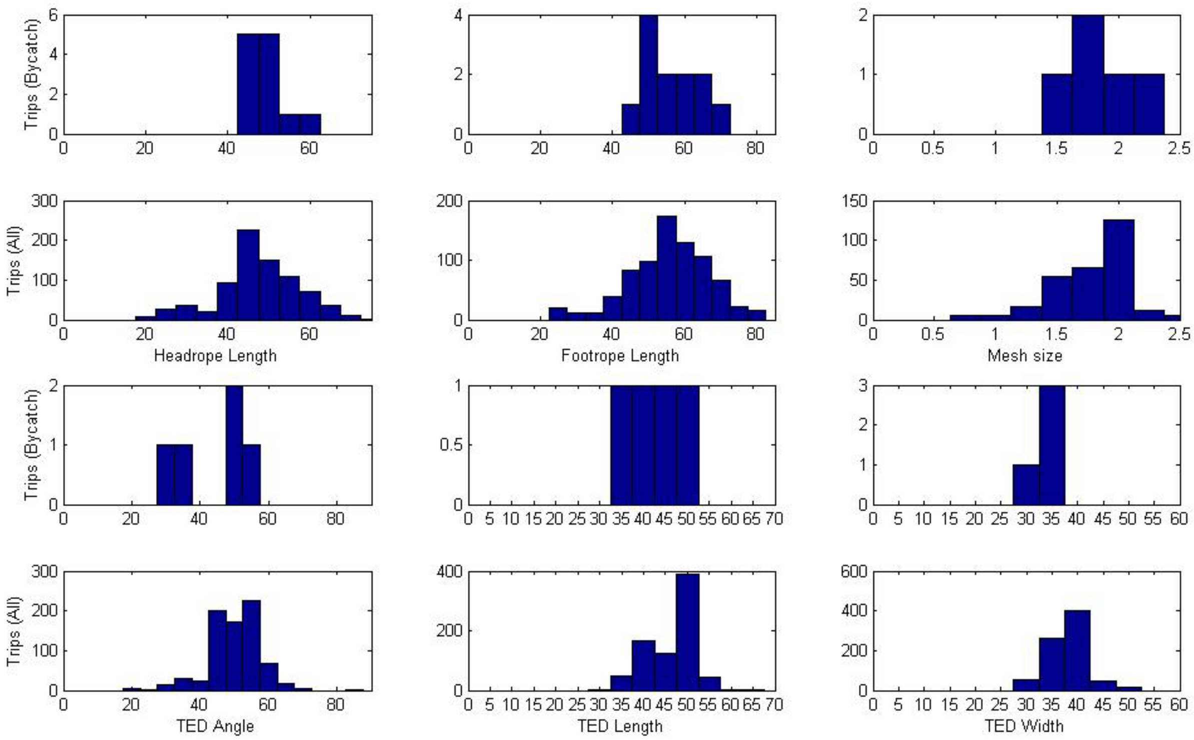
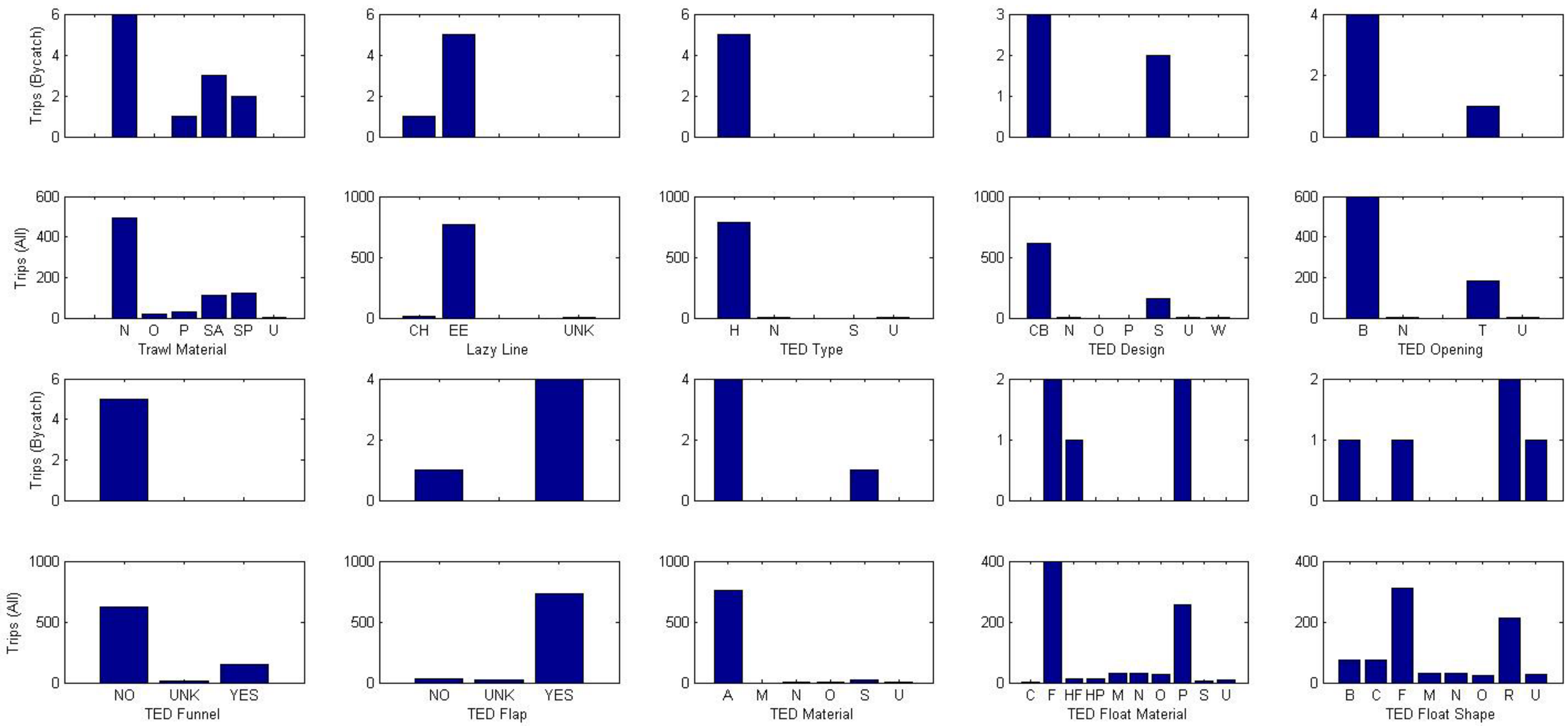


Figure 1. *Northern Gulf of Mexico bays and sounds. Each of the alpha-numerically designated blocks corresponds to one of the NMFS Southeast Fisheries Science Center logistical aerial survey areas listed in Table 1. The common bottlenose dolphins inhabiting each bay and sound are considered to comprise a unique stock for purposes of this assessment.*

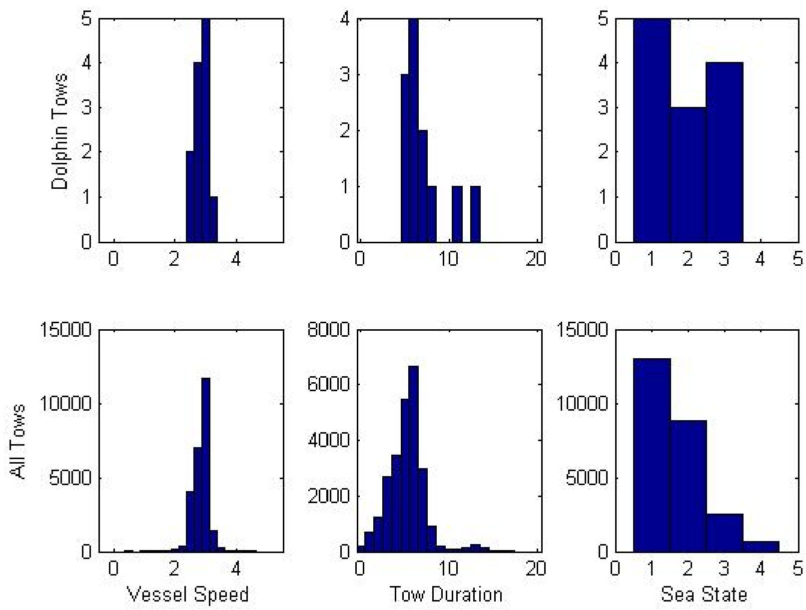
APPENDIX D



1. Comparison of numeric gear characteristics, including Turtle Excluder Device (TED) characteristics between Gulf of Mexico shrimp trawl Observer Program tows with marine mammal bycatch (upper panels per pair) and all tows (lower panels per pair). The effects of Headrope length, Footrope length, Mesh size, TED angle, TED length, and TED width are compared. For TED gear characteristics, only trips with bycatch in TED nets are included.



2. Comparison of class gear characteristics, including Lazy Line and Turtle Excluder Device (TED) characteristics between Gulf of Mexico shrimp trawl Observer Program trips with marine mammal bycatch (upper panels per pair) and all trips (lower panels per pair). The effects of lazy line rigging, TED type, TED design, TED Opening, Trawl material, TED funnel presences, TED flap presences, TED material, TED float material, and TED float shape are compared. For lazy line and TED characteristics, only trips with bycatch in lazy lines or TED nets, respectively, are included. Legend: Lazy line rigging: Elephant ears (EE), unknown (UNK), choke (CH). TED design: Curved bar (CB), unknown (U), weedless (W), straight (S), none (N). TED opening: Bottom (B), top (T), unknown (U), none (N). Trawl material: Spectra (SP), nylon (N), other (O), poly (P), sapphire (SA), unknown (U). TED material types: Aluminum (A), steel (S), unknown (U), none (N), other (O), mesh (M). TED float material: hard foam (HF), unknown (U), other (O), multiple (M), plastic (P), foam (F), hard plastic (HP), none (N), sponge (S), cork (C). TED float shape: Unknown (U), bullet (B), other (O), multiple (M), round (R), football (F), none (N), cylinder (C).



3. Comparison of tow operation characteristics between Gulf of Mexico shrimp trawl Observer Program tows with marine mammal bycatch (upper panels) and all tows (lower panels). The effects of vessel speed, tow duration, and sea state are compared. Tow durations were significantly higher for tows with marine mammal bycatch than for all tows.

APPENDIX E

1. Gulf of Mexico shrimp otter trawl fishery effort, Observer Program effort, marine mammal takes, and marine mammal bycatch rates for the 2-area stratified method of bycatch rate estimation. Species codes: Ud are unidentified dolphins, Tt are bottlenose dolphins (*T. truncatus*), and Sf are Atlantic spotted dolphins (*S. frontalis*). State areas are Florida (FL), Alabama/Mississippi (AL/MS), Louisiana (LA), and Texas (TX).

			Fishery Effort (1997-2011)		OP Effort (1997-2011)		Marine Mammal Takes			Marine Mammal Bycatch Rate (Takes per 1000 Hours)		
Area	Season	Depth Zone	Hours Fished	Est. Trips	Hours Fished	Trips	Sf Ud=Sf	Tt Ud=Sf	Tt Ud=Tt	Sf Ud=Sf	Tt Ud=Sf	Tt Ud=Tt
Eastern	1	In	216,094	4,045	3,739	70	1	0	1	0.267	0	0.267
Eastern	1	Near	443,823	8,309	3,739	70	1	0	1	0.267	0	0.267
Eastern	1	Off	2,370,536	22,326	8,494	80	1	0	1	0.118	0	0.118
Eastern	2	In	356,214	12,028	829	28	0	0	0	0	0	0
Eastern	2	Near	372,742	12,587	829	28	0	0	0	0	0	0
Eastern	2	Off	1,542,302	21,299	2,462	34	0	0	0	0	0	0
Eastern	3	In	129,104	10,782	192	16	0	0	0	0	0	0
Eastern	3	Near	357,148	29,826	192	16	0	0	0	0	0	0
Eastern	3	Off	1,272,539	11,549	2,755	25	0	0	0	0	0	0
Western	1	In	1,477,061	19,180	4,929	64	0	2	2	0	0.406	0.406
Western	1	Near	2,669,941	34,670	4,929	64	0	2	2	0	0.406	0.406
Western	1	Off	3,819,935	21,000	19,828	109	2	0	2	0.101	0	0.101
Western	2	In	7,434,941	87,006	14,527	170	0	0	0	0	0	0
Western	2	Near	9,515,797	111,357	14,527	170	0	0	0	0	0	0
Western	2	Off	10,152,653	70,526	32,246	224	0	0	0	0	0	0
Western	3	In	4,869,391	44,039	13,489	122	1	1	2	0.074	0.074	0.148
Western	3	Near	8,627,207	78,025	13,489	122	1	1	2	0.074	0.074	0.148
Western	3	Off	8,752,068	55,623	33,672	214	1	2	3	0.030	0.059	0.089

2. Total annual bycatch mortalities and CV of standard error of bottlenose dolphin (Tt) and spotted dolphin (Sf) stocks for the 2-area stratified method of bycatch rate estimation. The top panel presents results for the species scenario in which all unidentified dolphins are assigned to spotted dolphins, while the lower panel presents results for the species scenario in which all unidentified dolphins are assigned to bottlenose dolphins.

	Tt Shelf		Tt W Coastal		Tt N Coastal		Tt E Coastal		Tt TX BSE		Tt LA BSE		Tt AL/MS BSE		Tt FL BSE		Sf	
	Bycatch	CV	Bycatch	CV	Bycatch	CV	Bycatch	CV	Bycatch	CV	Bycatch	CV	Bycatch	CV	Bycatch	CV	Bycatch	CV
1997	49	0.68	168	0.58	4	0.68	0	-	25	0.80	15	1.02	11	0.70	0	-	0	-
1998	45	0.68	119	0.63	5	0.90	0	-	26	0.61	15	1.02	11	0.72	0	-	0	-
1999	44	0.68	221	0.58	10	0.60	0	-	26	0.57	20	0.88	15	0.74	0	-	0	-
2000	49	0.68	177	0.57	5	0.61	0	-	34	0.60	11	0.82	15	0.64	0	-	0	-
2001	53	0.68	201	0.57	5	0.67	0	-	21	0.66	14	1.01	18	0.62	0	-	0	-
2002	50	0.68	150	0.60	8	0.72	0	-	17	0.64	72	0.59	20	0.72	0	-	0	-
2003	41	0.68	91	0.63	5	0.60	0	-	10	0.67	44	0.59	15	0.70	0	-	0	-
2004	42	0.68	87	0.58	4	0.79	0	-	10	0.65	46	0.57	7	0.81	0	-	0	-
2005	28	0.68	53	0.57	5	0.59	0	-	8	0.57	35	0.58	5	0.60	0	-	0	-
2006	25	0.68	79	0.58	7	0.62	0	-	3	0.58	34	0.59	7	0.57	0	-	0	-
2007	24	0.68	61	0.58	7	0.58	0	-	4	0.73	28	0.57	8	0.64	0	-	0	-
2008	16	0.68	51	0.57	7	0.65	0	-	2	0.61	37	0.60	9	0.64	0	-	0	-
2009	18	0.68	69	0.58	12	0.58	0	-	2	0.64	71	0.60	14	0.61	0	-	0	-
2010	17	0.68	49	0.57	7	0.58	0	-	3	0.83	70	0.63	23	0.58	0	-	0	-
2011	20	0.68	50	0.57	5	0.60	0	-	1	0.64	63	0.59	18	0.58	0	-	0	-
1997	148	0.41	235	0.52	6	0.59	18	1.02	45	0.65	29	0.73	18	0.60	3	1.02	186	0.50
1998	150	0.42	183	0.56	10	0.68	23	1.02	39	0.55	31	0.73	18	0.61	2	1.02	197	0.48
1999	135	0.41	277	0.52	15	0.54	11	1.02	34	0.52	36	0.68	25	0.62	3	1.02	162	0.50
2000	129	0.41	235	0.52	8	0.54	15	1.02	40	0.54	20	0.66	23	0.57	8	1.02	155	0.50
2001	142	0.41	269	0.52	7	0.58	11	1.02	33	0.58	28	0.73	27	0.55	6	1.02	171	0.52
2002	140	0.42	220	0.54	14	0.61	12	1.02	26	0.57	87	0.53	33	0.61	6	1.02	179	0.53
2003	102	0.42	139	0.56	7	0.54	5	1.02	16	0.58	53	0.54	25	0.60	5	1.02	117	0.54
2004	112	0.44	122	0.53	7	0.64	5	1.02	15	0.57	59	0.52	12	0.65	2	1.02	114	0.50
2005	80	0.43	70	0.52	6	0.53	1	1.02	10	0.52	43	0.53	7	0.54	3	1.02	73	0.48
2006	65	0.41	100	0.52	8	0.57	6	1.02	4	0.52	41	0.53	9	0.52	3	1.02	69	0.47
2007	54	0.42	84	0.52	10	0.52	3	1.02	6	0.61	36	0.52	12	0.57	1	1.02	60	0.55
2008	39	0.42	70	0.52	11	0.57	1	1.02	3	0.54	45	0.54	14	0.57	1	1.02	45	0.58
2009	47	0.41	87	0.52	17	0.52	3	1.02	3	0.57	83	0.55	22	0.55	6	1.02	55	0.53
2010	49	0.41	66	0.52	8	0.52	3	1.02	5	0.66	78	0.58	29	0.52	6	1.02	55	0.49
2011	50	0.41	65	0.52	6	0.55	1	1.02	2	0.56	76	0.53	23	0.52	3	1.02	47	0.49

3. Gulf of Mexico shrimp fishery effort, Observer Program effort, marine mammal takes, and marine mammal bycatch rates for the 4-area stratified method of bycatch rate estimation. Species codes: Ud are unidentified dolphins, Tt are bottlenose dolphins (*T. truncatus*), and Sf are Atlantic spotted dolphins (*S. frontalis*). State areas are Florida (FL), Alabama/Mississippi (AL/MS), Louisiana (LA), and Texas (TX).

			Fishery Effort (1997-2011)		OP Effort (1997-2011)		Marine Mammal Takes			Marine Mammal Bycatch Rates (Takes per 1000 Hours)		
Area	Season	Depth Zone	Hours Fished	Est. Trips	Hours Fished	Trips	Sf Ud=Sf	Tt Ud=Sf	Tt Ud=Tt	Sf Ud=Sf	Tt Ud=Sf	Tt Ud=Tt
FL	1	In	216,094	4,045	3,739	70	1	0	1	0.267	0	0.267
FL	1	Near	443,823	8,309	3,739	70	1	0	1	0.267	0	0.267
FL	1	Off	2,370,536	22,326	8,494	80	1	0	1	0.118	0	0.118
FL	2	In	356,214	12,028	829	28	0	0	0	0	0	0
FL	2	Near	372,742	12,587	829	28	0	0	0	0	0	0
FL	2	Off	1,542,302	21,299	2,462	34	0	0	0	0	0	0
FL	3	In	129,104	10,782	192	16	0	0	0	0	0	0
FL	3	Near	357,148	29,826	192	16	0	0	0	0	0	0
FL	3	Off	1,272,539	11,549	2,755	25	0	0	0	0	0	0
AL/MS	1	In	227,703	4,595	1,239	25	0	1	1	0	0.807	0.807
AL/MS	1	Near	130,046	2,624	1,239	25	0	1	1	0	0.807	0.807
AL/MS	1	Off	344,729	3,275	3,790	36	0	0	0	0	0	0
AL/MS	2	In	2,279,786	45,837	2,537	51	0	0	0	0	0	0
AL/MS	2	Near	905,699	18,210	2,537	51	0	0	0	0	0	0
AL/MS	2	Off	1,017,412	11,410	6,153	69	0	0	0	0	0	0
AL/MS	3	In	1,375,589	21,766	3,223	51	1	0	1	0.310	0	0.310
AL/MS	3	Near	589,464	9,327	3,223	51	1	0	1	0.310	0	0.310
AL/MS	3	Off	834,412	11,838	4,934	70	0	0	0	0	0	0
LA	1	In	999,752	18,918	1,585	30	0	1	1	0	0.631	0.631
LA	1	Near	1,867,178	35,332	1,585	30	0	1	1	0	0.631	0.631
LA	1	Off	1,632,458	9,590	10,043	59	1	0	1	0.100	0	0.100
LA	2	In	3,334,617	23,626	9,033	64	0	0	0	0	0	0
LA	2	Near	7,472,619	52,944	9,033	64	0	0	0	0	0	0
LA	2	Off	5,029,567	55,841	8,647	96	0	0	0	0	0	0
LA	3	In	2,273,981	23,822	6,778	71	0	1	1	0	0.148	0.148
LA	3	Near	6,672,185	69,896	6,778	71	0	1	1	0	0.148	0.148
LA	3	Off	2,428,070	20,398	14,998	126	1	0	1	0.067	0	0.067
TX	1	In	249,606	1,779	2,104	15	0	0	0	0	0	0
TX	1	Near	672,718	4,795	2,104	15	0	0	0	0	0	0
TX	1	Off	1,842,748	15,981	5,996	52	1	0	1	0.167	0	0.167
TX	2	In	1,820,539	46,235	2,953	75	0	0	0	0	0	0
TX	2	Near	1,137,479	28,888	2,953	75	0	0	0	0	0	0
TX	2	Off	4,105,674	31,751	17,457	135	0	0	0	0	0	0
TX	3	In	1,219,821	10,444	3,504	30	0	0	0	0	0	0
TX	3	Near	1,365,558	11,692	3,504	30	0	0	0	0	0	0
TX	3	Off	5,489,586	43,958	13,737	110	0	2	2	0	0.146	0.146

4. Total annual bycatch mortalities and CV of standard error of bottlenose dolphin (Tt) and spotted dolphin (Sf) stocks for the 4-area stratified method of bycatch rate estimation. The top panel presents results for the species scenario in which all unidentified dolphins are assigned to spotted dolphins, while the lower panel presents results for the species scenario in which all unidentified dolphins are assigned to bottlenose dolphins

	Tt Shelf		Tt W Coastal		Tt N Coastal		Tt E Coastal		Tt TX BSE		Tt LA BSE		Tt AL/MS BSE		Tt FL BSE		Sf	
	Bycatch	CV	Bycatch	CV	Bycatch	CV	Bycatch	CV	Bycatch	CV	Bycatch	CV	Bycatch	CV	Bycatch	CV	Bycatch	CV
1997	73	0.67	217	0.84	3	0.84	0	-	0	-	29	1.00	8	0.84	0	-	0	-
1998	76	0.67	148	0.80	1	0.84	0	-	0	-	31	0.99	7	0.84	0	-	0	-
1999	70	0.67	289	0.91	11	0.84	0	-	0	-	38	0.89	9	0.84	0	-	0	-
2000	77	0.67	242	0.86	5	0.84	0	-	0	-	21	0.86	13	0.84	0	-	0	-
2001	77	0.67	291	0.85	4	0.84	0	-	0	-	28	0.99	17	0.84	0	-	0	-
2002	74	0.67	223	0.80	5	0.84	0	-	0	-	118	0.98	13	0.84	0	-	0	-
2003	61	0.67	133	0.79	5	0.84	0	-	0	-	72	1.00	11	0.84	0	-	0	-
2004	65	0.67	111	0.80	2	0.84	0	-	0	-	77	0.90	3	0.84	0	-	0	-
2005	44	0.67	66	0.84	7	0.84	0	-	0	-	57	0.96	5	0.84	0	-	0	-
2006	39	0.67	105	0.89	12	0.84	0	-	0	-	55	0.97	9	0.84	0	-	0	-
2007	32	0.67	81	0.85	9	0.84	0	-	0	-	47	0.90	7	0.84	0	-	0	-
2008	27	0.67	56	0.80	6	0.84	0	-	0	-	61	1.00	8	0.84	0	-	0	-
2009	31	0.67	77	0.89	15	0.84	0	-	0	-	116	1.02	14	0.84	0	-	0	-
2010	23	0.67	57	0.83	10	0.84	0	-	0	-	113	1.09	33	0.84	0	-	0	-
2011	32	0.67	67	0.91	9	0.84	0	-	0	-	104	0.98	26	0.84	0	-	0	-
1997	172	0.42	217	0.84	13	0.80	18	0.99	0	-	29	1.00	37	0.82	3	0.99	128	0.44
1998	180	0.43	148	0.80	20	0.95	23	0.99	0	-	31	0.99	37	0.83	2	0.99	146	0.44
1999	159	0.42	289	0.91	31	0.72	11	0.99	0	-	38	0.89	52	0.85	3	0.99	120	0.44
2000	156	0.43	242	0.86	15	0.72	15	0.99	0	-	21	0.86	47	0.77	8	0.99	105	0.44
2001	169	0.42	291	0.85	15	0.79	11	0.99	0	-	28	0.99	55	0.74	6	0.99	115	0.45
2002	166	0.42	223	0.80	29	0.84	12	0.99	0	-	118	0.98	69	0.84	6	0.99	128	0.44
2003	122	0.43	133	0.79	15	0.71	5	0.99	0	-	72	1.00	52	0.82	5	0.99	75	0.45
2004	132	0.43	111	0.80	14	0.88	5	0.99	0	-	77	0.90	26	0.90	2	0.99	84	0.46
2005	94	0.43	66	0.84	11	0.64	1	0.99	0	-	57	0.96	15	0.72	3	0.99	55	0.49
2006	77	0.43	105	0.89	16	0.67	6	0.99	0	-	55	0.97	17	0.64	3	0.99	49	0.44
2007	60	0.43	81	0.85	20	0.67	3	0.99	0	-	47	0.90	26	0.77	1	0.99	43	0.45
2008	46	0.44	56	0.80	22	0.77	1	0.99	0	-	61	1.00	28	0.76	1	0.99	37	0.53
2009	56	0.43	77	0.89	35	0.67	3	0.99	0	-	116	1.02	45	0.73	6	0.99	49	0.50
2010	57	0.40	57	0.83	17	0.64	3	0.99	0	-	113	1.09	58	0.64	6	0.99	44	0.42
2011	63	0.44	67	0.91	13	0.65	1	0.99	0	-	104	0.98	47	0.64	3	0.99	35	0.48